AD-A100 009 NETWORK ANALYSIS CORP VIENNA VA F/G 17/2
COMMUNICATIONS SUPPORT FOR AREA A AND REQUEST/REPLY.(U)
APR 81 DOT-FA79WA-4335
UNCLASSIFIED NAC/FR.303C FAA-RD-81-37 NL

1 OF 3
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Report No. FAA-RD-81-37

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COMMUNICATIONS SUPPORT FOR AREA A AND REQUEST/REPLY

NETWORK ANALYSIS CORPORATION
301 Tower Building
Vienna, VA 22180

APRIL 1981
FINAL REPORT

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Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

NOTICE

Technical Report Documentation Page

1. Report No.
FAA-RD-81-37

2. Government Accession No.
AD-A100 009

3. Recipient's Catalog No.

4. Title and Subtitle
COMMUNICATIONS SUPPORT FOR AREA A AND REQUEST/REPLY

5. Report Date
April 1981

6. Performing Organization Code

7. Author(s)

8. Performing Organization Report No.
FR.303C

9. Performing Organization Name and Address
Network Analysis Corporation
301 Tower Building
Vienna, VA 22180

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DOT-FA79WA-4335

12. Sponsoring Agency Name and Address
U.S. Department of Transportation
Federal Aviation Administration
System Research and Development Service
Washington, DC 20590

13. Type of Report and Period Covered
Final Report
1982 to 1991

14. Sponsoring Agency Code
FAA/ARD-200

15. Supplementary Notes

16. Abstract

Service A communication requirements were analyzed to determine the optimal communications support strategy, with NADIN integration as one of the primary alternatives to be evaluated. That analysis yielded the following conclusions:

- integration of Service A into NADIN will reduce monthly leased line recurring costs,
- NADIN use will result in little or no increase in total present value cost,
- Service A integration into NADIN is not feasible prior to WMSC replacement,
- WMSC Replacement design will be simplified by use of NADIN support for Service A, and
- NADIN will improve Service A performance by permitting cost effective circuit reconfiguration.

In addition the analysis determined detailed enhancements to NADIN required to support Service A while adequately maintaining other NADIN traffic.

17. Key Words
Data Communications
Requirements Analysis
Network Design
Cost-Benefit Analysis
NADIN
Service A and Request/Reply
WMSC

18. Distribution Statement
Document is available to the U.S. Public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
229

22. Price

Form DOT F 1700.7 (8-72)

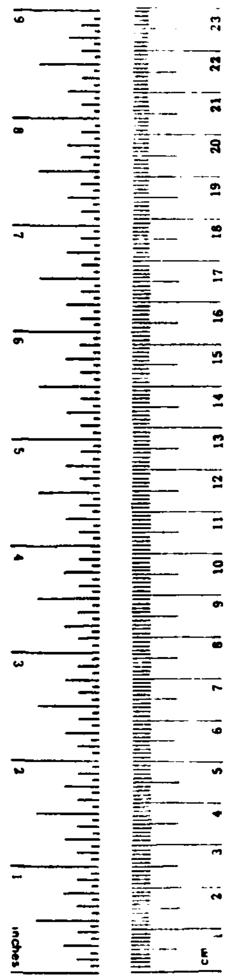
Reproduction of completed page authorized

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

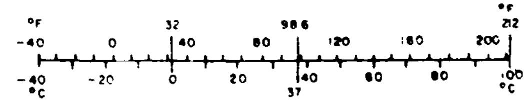
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and [illegible] see NBS [illegible] Units of Weights and Measures, Price $2.25, SD Catalog [illegible]



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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SECTION 1

INTRODUCTION

This report examines the feasibility and cost/benefit effectiveness of the National Airspace Data Interchange Network (NADIN) as a communications utility to connect Service A terminals, including Leased Service A (SAS), Area A, Request/Reply and ARTCC low-speed, with their weather information source. This source may be the WMSC or a replacement of the WMSC which is denoted WMSCR in this report. Specifically excluded from consideration are the military, non-government and Forecast Aviation Weather Service (FAWS) circuits in Service A.

In addition the requirements analysis data and traffic analysis in this document can be used to facilitate planning and study for the WMSC replacement program (i.e., the decommissioning of the WMSC).

1.1 FINDINGS

Findings are divided into primary ones, which relate to the study's objectives, and secondary ones which, while tangential to the study's main goals, warrant notice.

PRIMARY:

(1) Service A Integration into NADIN will reduce the monthly leased line recurring costs.
NADIN monthly recurring cost will be \$80,877/month vs. \$93,616/month for the current Service A approach.

(2) Integrating Service A into NADIN involves little or no difference in total costs.
Based on a cost cycle of eight years, total present value cost for use of NADIN versus continuation of the present Service A system are virtually identical. The NADIN cost includes one-time enhancement costs of \$870,470. However, a substantial portion of this one-time cost will be avoided if Service A is integrated into NADIN simultaneously with WMSC Replacement.

(3) Service A Integration into NADIN is not feasible prior to WMSC Replacement.
Software changes required to make the WMSC capable of supporting high speed NADIN interfaces in the manner needed to take full advantage of NADIN integration are substantial when viewed in the context of an old machine operating near the limits of its capacity scheduled for replacement within two years of NADIN's inception. However, it would not be difficult to design a new facility such as the WMSCR with the needed capabilities for high speed NADIN interfaces in support of Service A.

(4) The WMSC Replacement design will be simplified by use of NADIN to support Service A.
Use of NADIN would reduce the port requirements at the WMSCR for Service A support from more than one hundred low and medium speed ports to several high speed ports. It would also relieve the WMSCR of the bulk of the communications role (such as polling of numerous multipoint lines) now carried out by the WMSC.

(5) NADIN permits cost effective circuit reconfiguration which will improve Service A performance.
Use of NADIN makes it cost effective to reconfigure Service A circuits and reduce the stations per circuit ratio to obtain improved performance. Without NADIN similar reductions in the number of stations per circuit can of course be accomplished but at a significant increase in leased line costs. Delays for the interactive Request/Reply traffic will be reduced substantially by NADIN, 63% for medium speed circuits and 49% for low speed circuits.

(6) NADIN can support Service A while adequately maintaining other NADIN I traffic.
If the enhancements to NADIN discussed in this report are carried out, then NADIN can meet all of its performance specifications for the combined Service A and NADIN I traffic. These improvements consist of:

- increase in WMSC-NADIN trunk capacity or WMSCR-NADIN equivalent,
- increase in select Switch-Concentrator link capacity,

- software enhancements at NADIN Switch to handle routing, broadcast duplication and flow control,

- software enhancements at Concentrators to handle Service A polling and other protocol support functions,

- additional low and medium speed ports at NADIN Concentrators to accommodate Service A circuits (total of 186 ports),

(7) The WMSC or WMSC Replacement would require modifications to support Service A integration into NADIN.

These include:

- reassignment of ports including elimination of most low and medium speed ports and their replacement by a few high speed ports, and

- software to accommodate new addressing, routing, packaging of broadcasts and flow control.

SECONDARY:

(1) Delays in the National Weather Service-Automated Field Operations System (AFOS) Program could present an obstacle to integration of Service A into NADIN.

At present, Area A and Request/Reply circuits serve some National Weather Service facilities which are scheduled to leave for the AFOS before 1982. However, delays in the AFOS Program may mean that NWS users will remain on Area A and Request/Reply circuits for an indeterminate period beyond 1982. NADIN is a communications facility intended primarily for FAA use. Therefore, the persistence of NWS users on Area A and request/reply circuits would militate against integrating Service A into NADIN.

(2) Future programs to enhance Service A terminals or combine them with other services into multi-purpose facilities would be aided by the use of NADIN connectivity.

Interconnecting terminals to their hosts via a network such as NADIN has the significant effect of eliminating the dependency of the terminal on the host interface. NADIN supports interfaces with various types of terminals via several different protocols and codes. This provides great flexibility for possible future consolidation of Service A terminals with Service B and/or other terminals sharing NADIN connectivity. Not only does NADIN provide the physical interconnection to diverse hosts, but it supports the possibly different protocols of those hosts making them compatible with use of multi-purpose terminals.

1.2 INTERPRETATION OF FINDINGS

Service A integration into NADIN offers improved performance at lower monthly recurring cost. However, NADIN use prior to the WMSC replacement is not operationally feasible since it involves a substantial one time cost and large manpower effort which cannot be recovered over the short remaining lifespan of the WMSC. However, the cost figures show that concurrent WMSC Replacement and Service A integration into NADIN will afford the same substantial monthly savings while incurring essentially no additional start up costs for the WMSCR than without NADIN. If NWS users leave Area A and Request/Reply circuits before WMSC Replacement the NADIN alternative is preferable to a NADIN-independent Service A. The immediate NADIN advantage under this scenario is improved performance and lower cost while the longer term advantage is increased flexibility to improve terminal facilities or utilize an alternative weather data source. On the other hand, NADIN use is contra-indicated if the NWS users are anticipated to remain on Area A and Request/Reply circuits beyond WMSC Replacement.

1.3 BASIS

The performance and cost results in this report are based on the following assumptions:

(1) Immediately prior to Service A integration, NADIN traffic will consist only of the initial NADIN 1 traffic as described in Appendix Z, NADIN Specifications.

(2) The Service A terminal population will remain stable over the 1982-1990 period except for planned AFSS installations.

(3) The National Weather Service Terminals will have left Area A and Request/Reply circuits before WMSC replacement.

(4) NADIN initial costs are treated as a sunken investment.

(5) Service A hardware costs are included only in case they are dependent on the alternative chosen.

1.4 METHODOLOGY

The following steps led to the findings in Section 1.1:

(1) A requirements analysis was completed to determine traffic requirements and nodal characteristics.
This work was reported in NAC working memo WM.303C.05, Service A and Request/Reply Requirements Analysis.

(2) A design analysis was carried out to determine the local extension of NADIN to Support Service A.
The local access design describes the optimal multipoint-line layouts for the various classes of Service A circuits in each ARTCC region, terminating at the NADIN concentrator, which were obtained in Working Memo WM303C.06, Local Expansion of NADIN to Support Service A. Local access delays and throughput results were included in that memorandum.

(3) The hardware and software modifications needed for the NADIN backbone and WMSC-NADIN interface to accommodate Service A were determined.
These results together with network performance for both Service A and NADIN 1 traffic were reported in Working Memorandum WM.303C.07, Service A and Request/Reply Integration.

(4) A cost/benefit comparison was made based on Steps 1, 2 and 3.

This work comprised WM.303C.08, Service A Comparative Evaluation, in which the non-NADIN and two NADIN alternatives were costed in detail based on the local access and backbone designs obtained in Steps (2) and (3).

1.5 CHARTER

The National Airspace Data Interchange Network (NADIN) is being developed, in its initial phase, as a common data communications network that will integrate various FAA communications services, specifically those involved in the exchange of information pertaining to air traffic. Current FAA plans call for the implementation of NADIN in the early 1980s. The initial design is specifically directed to the absorption of the Aeronautical Fixed Telecommunciation Network (AFTN), NASNET, and most of Service B. The design also provides for the expansion of NADIN facilities and circuits so as to accommodate growth, both in terms of requirements for included services and in terms of additional services.

Concurrently with efforts to implement the initial NADIN design, efforts are being directed to the analysis of other services that might be integrated into NADIN. These analyses have two major objectives. First they are to determine if the integration of the specific service into NADIN is cost/beneficial. Second, they are to determine the specific enhancements to NADIN that would be required to support that service. This report documents such an analysis with respect to the Area A and Request/Reply service, and is the draft final report under Task 6 of contract DOT-FA79WA-4355.

1.6 ORGANIZATION

The remainder of this report is divided into three major sections:

- Section 2 which presents the detailed results on Cost, Design, Performance, and Traffic from which the findings in Section 1.1 follow.

- Section 3 discusses the basis and documentation for each of these categories of results.

- Section 4 includes the detailed modeling and analysis used to obtain the results of Section 2.

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SECTION 2

RESULTS

This section presents the major results of the study on which the findings in Section 1 are based. The network alternatives are described including both their topological and functional properties. Costs are presented next, including one-time and monthly recurring costs all reduced to a present value total for comparison purposes. Performance of the alternatives including delays for both Service A and NADIN I base traffic are discussed. Finally, the traffic flows in the various approaches are outlined.

2.1 THE NETWORK ALTERNATIVES

Service A communication needs can be met by a NADIN-independent network or by one integrated with NADIN. In this section these alternative approaches are presented including two NADIN subalternatives.

2.1.1 The Non-NADIN Alternative - Alternative 1

The portion of Serv'ce A being evaluated in this study consists of Leased Service A, Area A, Request/Reply and ARTCC single node circuits. In the non-NADIN alternative (Alternative 1) all circuits eminate from the WMSC in Kansas City via multipoint or point-to-point lines to the users in the conterminous United States (CONUS), Alaska, Hawaii and Puerto Rico. For cost and performance comparison purposes all alternatives are considered for CONUS only (except that total Switch and WMSC traffic loads do include Alaska, Hawaii and Puerto Rico). The classes of circuits in the 1982 environment will be:

- Area Circuits - 40 Half duplex 75 b/s multipoint teletype circuits in CONUS for distribution and collection of weather data to FAA users.

- Request/Reply - 40 Half duplex 75 b/s multipoint teletype circuits in CONUS which roughly parallel the FAA Area Circuits and enable government flight briefing facilities to obtain information not routinely distributed on area circuits.

- ARTCC Circuits - Full Duplex 75 b/s point-to-point teletype circuits to twenty CONUS and one Alaska ARTCC used for Request/Reply, receipt and transmission of certain flight related weather information.

- SAS Circuits - 18 Full duplex 2400 b/s multipoint circuits used exclusively for SAS FAA sites for Request/Reply receipt and transmission of flight related weather information.

Area A circuit #23 is shown in Figure 2-1 as it might be configured in 1982 with the node population then extant. For cost and performance purposes it is assumed that Alternative 1 would contain 40 Area A and 40 Request/Reply circuits in the 1982-1990 time frame although in fact some consolidation of circuits will almost certainly take place as low speed terminals are replaced by medium speed facilities. The projected 1982 terminal populations are:

- Area A - 261 Terminals in CONUS plus 34 in Alaska

- Request/Reply - 173 Terminals in CONUS plus 16 in Alaska

- ARTCC - 20 Terminals in CONUS plus one in Alaska

- SAS - 145 Controllers in CONUS plus 4 in Alaska. These in turn serve 1345 Keyboard Video Display Terminals (KVDTs).

A more detailed description of the nodal population for 1982 is contained in Section 3.1.1 and Appendices A, B, C and D.

2.1.2 The NADIN Alternatives - Alternatives 2.1 and 2.2

The Service A nodal population extant in 1982 as described in 2.1.1 would be reconfigured into new multipoint lines homed on their individual ARTCC concentrator and then via NADIN to the WMSC in Kansas City. The four types of circuits, namely, Area A, Request/Reply, ARTCC, and medium speed leased Service A (SAS) discussed in 2.1.1 will all continue to exist as distinct circuits. The conceptual use of the NADIN network for Service A is illustrated in Figure 2-2.

For NADIN to support the integration of Service A a number of modifications are necessary. These fall into two categories, changes in link capacities and special functions. In particular, two alternative implementations Alt. 2.1 and 2.2 for NADIN are identified which differ only in their WMSC - SWITCH link configurations.

2.1.2.1 Links

The addition of Service A traffic requires the line capacity between the WMSC and the NADIN switches to be increased to meet NADIN performance specifications. The 4.8 Kb/s lines from switches to concentrators are adequate for an average center (ARTCC), but several larger centers require increased line capacity. Even an average center experiences a significant increase in traffic on the switch-to-concentrator links. This increased flow causes a loss of reserve capacity which might be considered a NADIN resource expended.

WMSC-Switch Links

The WMSC is an operational system that has been in existence providing weather services to both FAA and external users for a long period of time. The decommissioning of the WMSC is now planned for 1985. Therefore, the links discussed here are illustrations of link capacity and features required for the WMSC or an equivalent processor denoted WMSCR to interface NADIN. The actual WMSCR-NADIN interface might be implemented in a variety of ways but these variations would have little effect on the detailed system performance analysis or month recurring cost analysis in this report.

One of the features recommended for this link is use of flow control to avoid the need for excess buffer capacity at the switch during broadcasts. In particular non broadcast traffic can be accommodated by 3.8 Kbytes of buffering at a switch with .95 probability of non-overflow. However, to accommodate broadcast traffic an additional 105 Kbytes of buffer would be required in the absence of flow control. This control could be accomplished by use of NADIN advisory messages.

Each switch would be served by three physically separate lines from the WMSC: two 19.2 Kb/s full-duplex lines and one 2.4 Kb/s full-duplex line. The need for these lines is addressed in Section 4.1. The functions of these circuits are as follows:

- One 19.2 Kb/s line per switch for SAS broadcast and collection (as described in NADIN Specifications, Appendix Z).

- One 19.2 Kb/s line per switch for Request/Reply traffic from both low- and medium-speed terminals as well as Level I Type II and III traffic.

- One 2.4 Kb/s line per switch for broadcast and collection for the low-speed Area A and ARTCC terminal nodes (Z-nodes).

The two subalternatives for NADIN differ only in the manner in which these WMSC-Switch circuits are implemented. Alternative 2.1 calls for three physically separate lines from the switches all the way to Kansas City, as illustrated in Figures 2-3 and 2-4. Under Alternative 2.2 the three circuits would be multiplexed and carried on a Dataphone Digital Service (DDS) 50 Kb/s line, as shown in Figure 2-5.

Switch-to-Concentrator Links

Line speed, switch service discipline, and concentrator buffering all require modifications for optimal results. Regarding line speeds, two types of centers are distinguished: an average center with 3 or fewer SAS circuits (as listed in Section 4.1); a large center with 4 or 5 SAS circuits. There are three large centers by this definition: Miami (ZMA), Houston (ZHV), and Albuquerque (ZAB). The complete list of line capacities is shown in Table 2-1. The analysis which leads to the choice of these facilities is described in Section 4.3.

To ensure continuity of messages arriving at a concentrator from the switch, switch service discipline and a "window" mechanism at the concentrator are recommended. The window is a buffer space at the concentrator which can accommodate two or more frames destined to a given output port. Therefore the switch can send a frame to a concentrator output port even if the transmission of the previous frame to the same output post is not completed. As a result a delay between two frames will be perceived at the receiving end only if the time taken by the switch to give its attention to the last frame, plus the time of transmission over the switch-to-concentrator line, exceeds the time taken to transmit the two previous frames over an output line at the concentrator. This issue as well as a detailed discussion of the switch service discipline is presented in Section 3.3.1.

2.1.2.2 NADIN Functional Enhancements

Integration of Service A into NADIN will require that a number of functional modifications be undertaken at the NADIN switches and concentrators as well as at the WMSC.

WMSC Function Requirements

The WMSC or its replacement would require only a few operational changes under the NADIN integration alternatives. Those needed are:

- revision of weather products distribution tables to reflect new allocation of broadcast information,
- reassignment of output ports,
- ability to respond to advisory messages from a NADIN switch to temporarily cease broadcasts over either of the two separate broadcast lines while maintaining transmission over the third short-message line.

NADIN Switch Function Requirements

The NADIN switches are required to perform several special functions to support Service A.

- Duplication of Broadcasts — One copy of the broadcast to be distributed to the multiple Area A Circuits of an individual enroute area as well as one copy of the broadcast for the SAS circuits of an individual enroute area are sent to the appropriate switch by the WMSC. It is the switch's responsibility to recognize the correct number of duplications required for each broadcast - based upon its ARTCC destination and to produce multiple copies for transmission to the concentrator.

- Routing tables at each switch must be expanded to accommodate addressing for the approximately 650 Service A terminals.

- Advisory messages are to be sent to the WMSC to call for cessation of broadcast over one or the other of the two broadcast lines from the WMSC whenever a large backlog of broadcast frames awaiting service accumulates at the switch.

2.1.2.3 Concentrator Function Requirements

- Service A circuits require an average of 10 concentrator ports per ARTCC, including a mix of low- and medium-speed.

- The concentrator is required to support terminal protocols: for example, by assuming polling functions for Request/Reply circuits.

2.2 COSTS

The non-NADIN alternative (Alternative 1) costs more per month than either of the NADIN approaches (Alternative 2.1 and Alternative 2.2). However, the NADIN integration of Service A involves significant startup costs (one time) not encountered in Alternative 1. These one time costs for NADIN integration include items for WMSC modifications. If WMSC Replacement and NADIN integration are concurrent then these modification costs can be largely deleted since use of NADIN will probably reduce rather than increase WMSC Replacement costs. However, at this stage in the WMSC Replacement program it is difficult to give estimates of these savings. Costs for the various alternatives based on modifying today's WMSC are:

- Alternative 1 (non-NADIN) - Monthly Recurring Cost (MRC) equals $93,610.

- Alternative 2.1 (NADIN) - MRC equals $80,880; one-time cost equals $870,470.

- Alternative 2.2 (NADIN) - MRC equals $84,550; one-time cost equals $696,110.

In order to make a comparison between the costs of the various approaches, all costs are reduced to a single present value cost (discussed in Appendix E) and displayed in Table 2-2. *Figure 2-6 shows this information graphically.* The most striking result is the very slight difference in cost over a seven to ten year life cycle. Several other features can be noted.

The use of Alternative 2.2 is not cost-effective as it is never the least costly over any life cycle. Of course, if Telpak tariffs were to be eliminated in the near future, then Alternative 2.2, specifically the use of DDS on the WMSC-Switch link, might be cost-effective.

In the following subsections the constituent costs of the three alternatives are discussed. All tariff-dependent costs are based on GSA Telpak rates except for the two DDS links in Alternative 2.2. It is assumed that the Interexchange Mileage (IXCM) will be the same for all three alternatives. The total IXCM used is based on a 7/23/80 Financial Report Printout provided by FAA adjusted to reflect expected node changes by 1982. In addition, GSA Telpak levies a 1.5% monthly service fee on all monthly recurring line and drop charges. This rate is the same for all three alternatives. Finally, although it is recognized that Telpak tariffs may be discontinued, it is not clear when this might happen or what, if any, new tariff might replace it. Since all alternatives are costed using Telpak, the comparative evaluation should be valid even under a different tariff structure. If a new tariff is used which substantially increases line costs, then the NADIN *alternatives become* more attractive as they result in lower mileage than the non-NADIN approach.

2.2.1 Costs for the Non-NADIN Alternative (CONUS only)

If Service A is not integrated into NADIN, the total recurring monthly cost will be $93,610 which includes mileage charges (including IXCM), drop charges and Telpak service fee. No hardware costs are included except for the leased Service A modem charges which are included on a monthly lease basis at $60/month. The costs can be divided into mileage, drop and service charges, and modem charges, as shown:

- $51,970/mo.-mileage charge (includes IXCM)
- $30,740/mo.-drop charges
- $1,240/mo.- service charges
- $9,660/mo.- SAS modem leasing.

There are no one-time fixed costs considered because the non-NADIN alternative involves continuation of an already existing system.

2.2.2 The NADIN Alternatives

Two subalternative plans for integration of Service A into NADIN are costed in this section. The two are identical in all features except for the WMSC-Switch links. Alternative 2.1 calls for using two 19.2 kb/s lines (each configured from two 9.6 kb/s lines with biplexors), and one 2.4 kb/s, full-duplex line from each NADIN switch to the WMSC. Alternative 2.2 uses two synchronous ports at 19.2 kb/s and one at 2.4 kb/s, respectively, as in Alternative 2.1 but these lines are multiplexed and carried on Dataphone Digital Service (DDS) from the WMSC to each switch. These alternatives are illustrated in Figures 2-3, 2-4 and 2-5.

The monthly recurring costs for the two NADIN subalternatives are:

- $80,880/mo. for Alternative 2.1
- $84,550/mo. for Alternative 2.2

The total one-time costs for each are:

- $870,470 for Alternative 2.1
- $696,110 for Alternative 2.2

These two categories of costs, recurring monthly and one-time costs, are itemized in Section 4.2.1.

Costs for these two NADIN approaches are very close with Alternative 2.2 being the more expensive for life cycles of more than five years and the less expensive for shorter life cycles. However, it is only for the longer life cycle that either of the NADIN alternatives is superior to the non-NADIN approach, so that on a cost basis, Alternative 2.1 is judged preferable to 2.2.

In addition, Alternative 2.1 provides greater flexibility and reliability since failure of any one of the five physically separate lines from WMSC to Switch in Alternative 2.1 still permits delivery of weather data to Service A users. This consideration is quantified in Appendix F.

For both these reasons, the preferable of the two NADIN subalternatives is Alternative 2.1.

2.3 PERFORMANCE COMPARISON

Both of the NADIN subalternatives 2.1 and 2.2 are considered identical in performance and superior to the non-NADIN Alternative 1. The improvement is gained in handling of short message traffic, while broadcast is essentially unchanged by any of the alternatives. Specifically, delays for requests for both low and medium speed terminals as well as for replies for low speed terminals are reduced significantly. Medium speed reply delays are not affected significantly.

2.3.1 Medium Speed Request/Reply Delays

The average reply delays from the appearance of a reply at WMSC to the receipt of the first character at a leased Service A controller unit are:

- 1.62 seconds for the NADIN alternative.
- 1.57 seconds for the non-NADIN alternative.

The average request delays from the appearance of a request at a leased Service A controller unit to the receipt of the last character at WMSC are:

- 1.3 seconds for the NADIN alternative.
- 3.7 seconds for the non-NADIN alternative.

The reason for NADIN's advantage is that the use of the NADIN trunk capacity to replace the current long haul multipoint lines of Service A makes it cost-effective to

configure circuits with fewer nodes. In particular, the NAC optimization algorithm used for the local access design resulted in an average of 3 SAS nodes (controllers) per circuit as opposed to approximately 8 SAS nodes per circuit without NADIN.

These delays are based on the analysis in Section 4.3 and the Appendices.

2.3.2 Low Speed Request/Reply Delays

Low speed Request/Reply delays are significant under any of the alternatives considered although substantially reduced in the NADIN Alternatives 2.1 and 2.2. The polling with its long 5 second timeouts contributes significantly to these delays. Alternative 2 makes cost-effective the use of multipoint lines with 3 nodes per circuit as opposed to the non-NADIN average of 4.5 nodes per circuit.

The average reply delays from the WMSC to a low speed Request/Reply terminal are:

- 15 seconds for Alternative 2 (NADIN)
- 21 seconds for Alternative 1 (non-NADIN)

The average request delays from a low speed terminal to the WMSC are:

- 24 seconds for Alternative 2 (NADIN)
- 56 seconds for Alternative 1 (non-NADIN)

The local access delays for Alternative 2 and the delays for Alternative 1 are based on the analysis in Section 4.3.8 while the WMSC-Switch and Switch-Concentrator delays are derived in Sections 4.3.1, 4.3.2, 4.3.3 and 4.3.4.

2.3.3 NADIN I Delays

One of the major criteria in assessing the feasibility of integrating Service A into NADIN is the effect of added traffic load on NADIN's ability to satisfy the performance requirements for NADIN I traffic. There are many components of NADIN I traffic but for purposes of examining delay requirements it suffices to look at the greatest delays for all traffic on three paths.

- The average delay for all NADIN I traffic from concentrator-to-switch-to-WMSC is less than .4 seconds.

- The average delay for all NADIN I traffic from the WMSC-to-switch-to-concentrator is less than 1.8 seconds.

- The average delay for all NADIN I traffic from concentrator A-to-switch B-to-switch C-to-concentrator D is less than 1.9 seconds.

The average delay on each link and for each user is discussed in detail in Section 4.3.1.5, 4.3.2.3, 4.3.3, 4.3.4.3 and 4.3.5. In all cases the delays meet NADIN Specifications, Appendix Z.

2.3.4 Priority 1 Delays

The highest priority messages in the NADIN priority scheme are the Priority 1 messages, which are short messages (average 120 chartacters), usually concerning network operation. No Service A messages are of this priority; in fact, all Service A messages are classed as NADIN Priorities 3 or 4. In Section 4.3.6 Priority 1 messages are shown to experience delays of less than .33 seconds on either the WMSC-switch links or the switch-concentrator links — well within the NADIN specifications of an end-to-end average delay of less than 1.5 seconds. For an extreme example, if a Priority 1 message were sent from concentrator A to Switch East to Switch West to concentrator B, the accumulated delay would be less than 1.32 seconds.

2.3.5 Buffer Requirements

Buffer requirements at the switch will vary depending on whether and in precisely what manner flow control for broadcast from the WMSC to switch is established. For purposes of comparison buffer capacity at the switch for reply traffic to obtain 95% probability of non-overflow during a period of no broadcast to the medium speed SAS circuits is found to be 3.8 Kilobytes. This does not include buffer capacity for Service A frames in partial state of completion (which would req[illegible] an additional capacity of at most 3 K[illegible]tes) but only for frames waiting for attention from the switch.

During the SA broadcast to low and medium speed circuits an additional buffer capacity of 105 Kilobytes is required in the absence of flow control to handle storage of broadcast frames at the switch awaiting forwarding to the various concentrators. The increased capacity is more than one order of magnitude greater than would be needed with flow control.

2.3.6 Broadcast and Collection of Weather Data

There is little difference in the performance of the NADIN versus Non-NADIN alternatives in broadcast and collection of weather data. End-to-end delays are of the order of 1.5 seconds which is of little consequence for this type of traffic. One measure of adequacy for this largely scheduled traffic is the length of time required to complete various portions of broadcast or collection such as the scheduled SA broadcast commencing at H+03 or the scheduled A1 Scan. Table 2-3 shows the comparison between NADIN and non-NADIN completion times based on the largest circuit of a given type.

2.4 TRAFFIC RESULTS

The addition of Service A traffic to the NADIN I base traffic will have a number of effects.

- Throughput on the switch to concentrator links will increase by a factor of approximately 3.4.
- Throughput on the WMSC-NADIN interface will increase by a factor of 11.5.
- Large broadcasts will comprise nearly 50% of all throughput on switch to concentrator links.
- Virtually all Service A traffic is centralized, flowing from the WMSC-to-switch-to-concentrator-to-DTE or the reverse.
- No Service A traffic will flow (normally) on the switch to switch link.

A summary of NADIN I and Service A traffic appears in Table 2-4. Integration of Service A will change NADIN from a carrier of short message traffic to a handler of large broadcasts, medium length messages (Replies) and short messages. This traffic can be accommodated by NADIN with acceptable delays and reasonable buffer requirements if the enhancements to NADIN described in Section 2.1 are carried out.

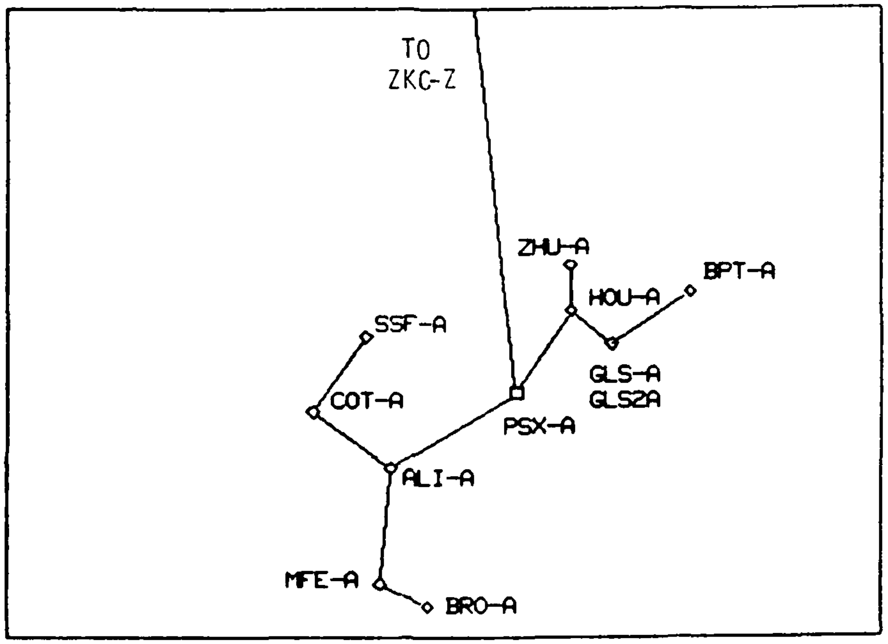


FIGURE 2-1: SIMULATED LAYOUT AREA A CKT. #23 (1982)
(NON-NADIN ALT.1)

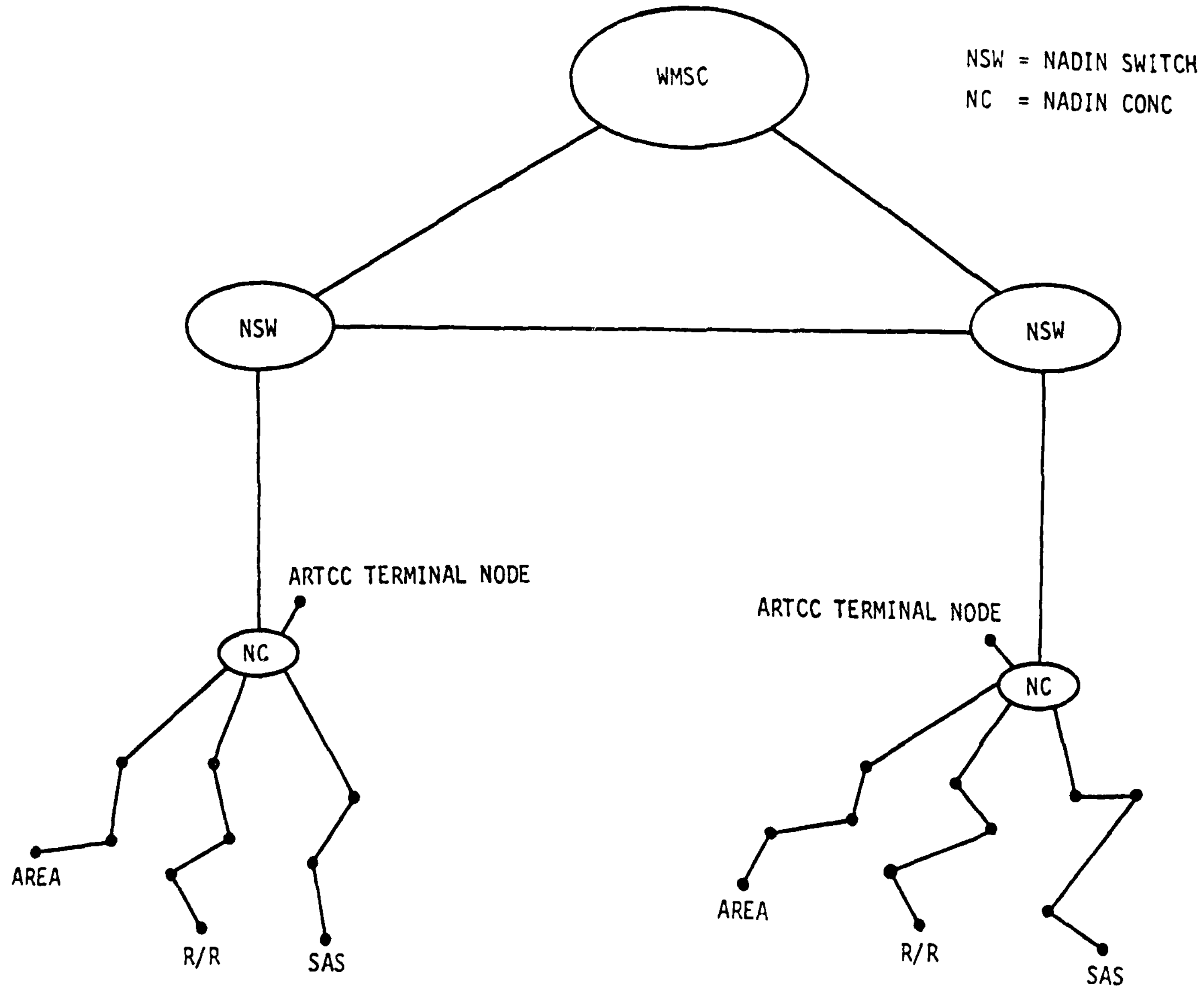


FIGURE 2-[illegible]: CONCEPTUAL USE OF NADIN TO SUPPORT SERVICE A

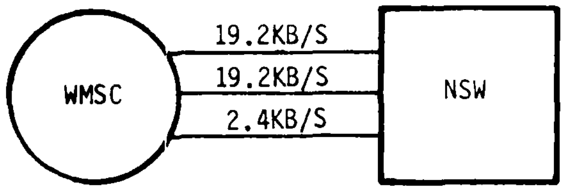


FIGURE 2-3: NADIN ALT.2.1:
WMSC - SWITCH LINK

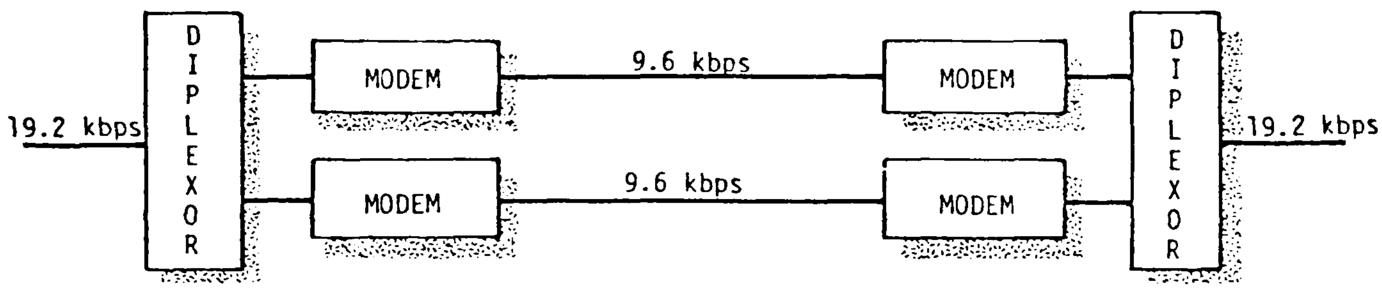


FIGURE 2-4: 19.2 KBPS LINE CONFIGURATION

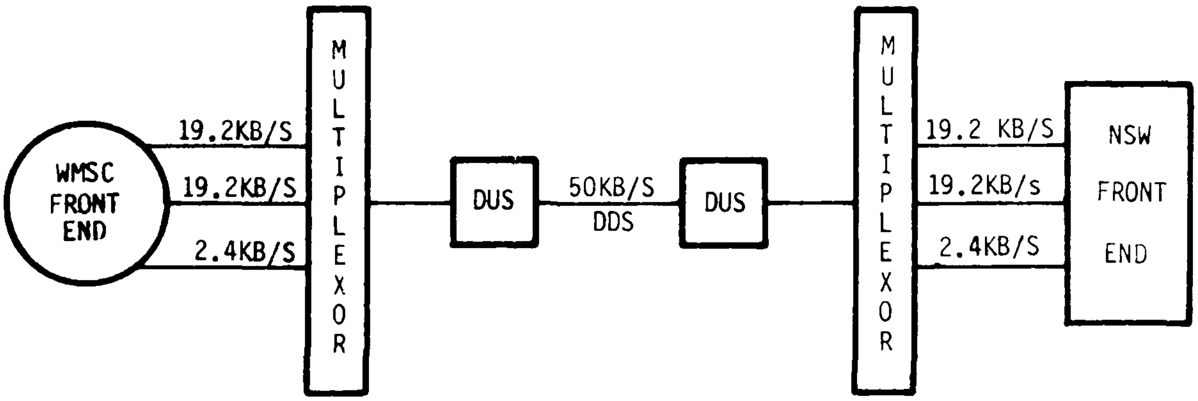


FIGURE 2-5: NADIN ALT. 2.2 USE OF DDS FOR WMSC-SWITCH LINK

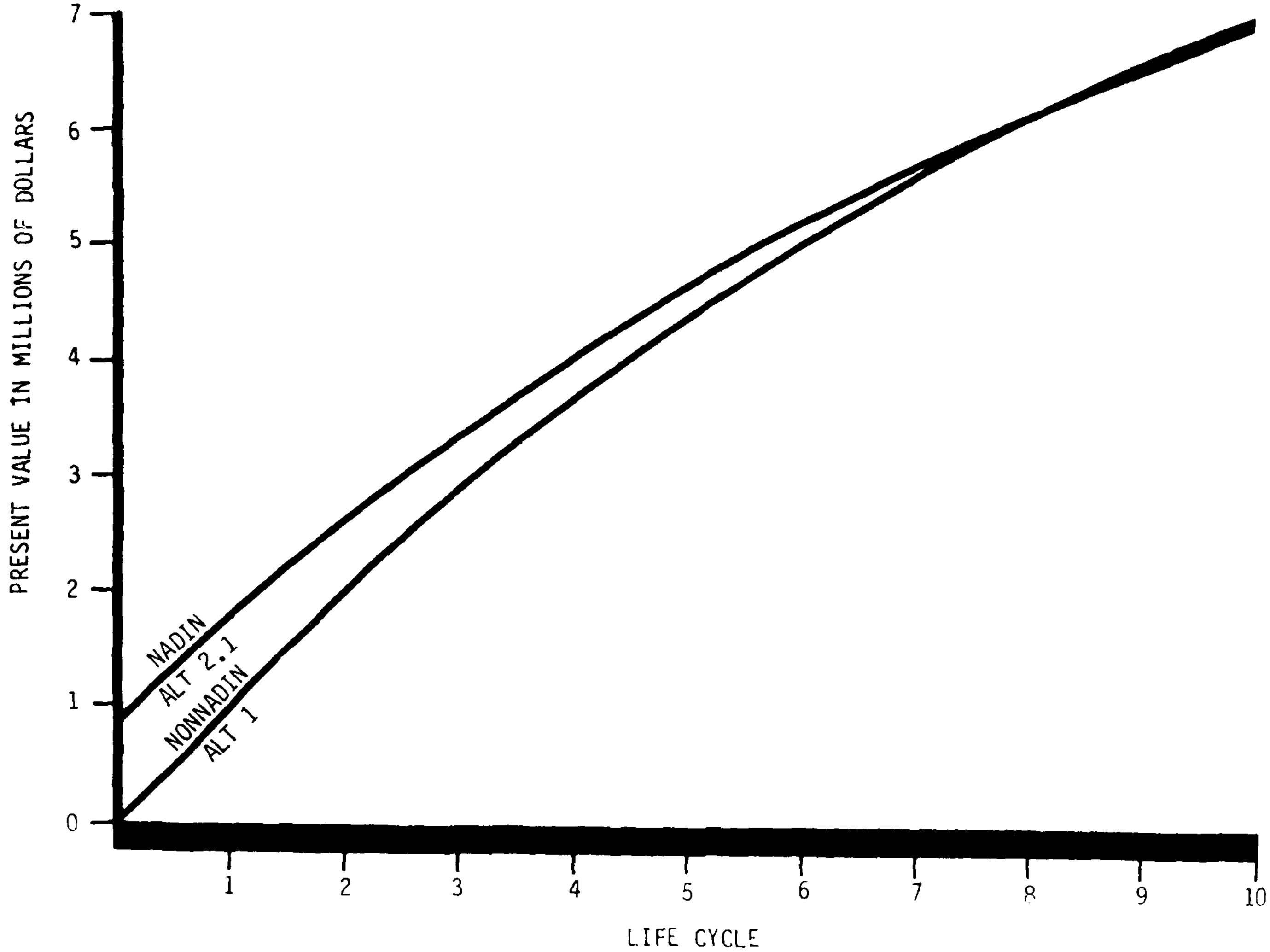


FIGURE 2-6: TOTAL PRESENT VALUE COMPARISON (BASED ON TABLE 2.1)

CITY	NADIN ID	4.8 K/bs	9.6 Kb/s
Boston	ZAB		X
Chicago	ZAU	X	
Albuquerque	ZBW	X	
Washington, DC	ZDC	X	
Denver	ZDV	X	
Fort Worth	ZFW	X	
Houston	ZHU		X
Indianapolis	ZID	X	
Jacksonville	ZJX	X	
Kansas City	ZKC	X	
Los Angeles	ZLA	X	
Salt Lake City	ZLC	X	
Miami	ZMA		X
Memphis	ZME	X	
Minneapolis	ZMP	X	
New York	ZNY	X	
Oakland	ZOA	X	
Cleveland	ZOB	X	
Seattle	ZSE	X	
Atlanta	ZTL	X	

TABLE 2-1: SWITCH-TO-CONCENTRATOR LINK

LIFE CYCLE (YEARS)	ALTERNATIVE 1 NON-NADIN	ALTERNATIVE 2.1 NADIN	ALTERNATIVE 2.2 NADIN
1	$1,067,222	$1,792,470	$1,659,990
2	$2,003,380	$2,601,240	$2,505,500
3	$2,902,100	$3,377,660	$3,317,190
4	$3,688,470	$4,057,020	$4,027,420
5	$4,409,310	$4,679,780	$4,678,460
6	$5,055,260	$5,237,830	$5,261,860
7	$5,635,680	$5,739,270	$5,786,080
8	$6,169,290	$6,200,260	$6,268,020
9	$6,646,740	$6,612,740	$6,699,230
10	$7,086,730	$6,992,860	$7,096,620

	MONTHLY RECURRING COST	ONE TIME COST
NON-NADIN	$ 93,610	--------
NADIN ALT. 2.1	$ 80,880	$ 870,470
NADIN ALT. 2.2	$ 84,550	$ 696,110

TABLE 2-2: TOTAL PRESENT VALUE COST (7/30/80)

	SAS		AREA A	
	NADIN	NON-NADIN	NADIN	NON-NADIN
TOTAL BROADCAST	8.76	8.76	42.3	39.6
SA BROADCAST	2.49	2.49	11.7	11.0
TOTAL COLLECTION	1.3	.73	2.1	2.1
SA COLLECTION	.89	.5	1.26	1.26

TABLE 2-3 BROADCAST AND COLLECTION COMPARISON
(MIN./HR)

TRAFFIC OUTBOUND FROM WMSC

MESSAGE TYPE	WMSC TO LARGER NADIN SWITCH		SWITCH TO AVERAGE CONCENTRATOR		CHAR/MSG
	MSG/HR	Kb/SEC	MSG/HR	Kb/SEC	
NADIN I-TYPE II	1,116	.3	756	.20	120
NADIN I-TYPE III	48	.32	14	.09	3,000
SAS BROADCAST	268	2.2	59	.48	3,700
AREA A BROADCAST	80	.66	18	.14	3,700
SAS REPLY	2,740	4.2	229	.35	690
LOW SPEED REPLY	278	.43	23	.04	690
TOTAL	4,530	8.11	1,099	1.3	

TABLE 2-4a NADIN-WMSC TRAFFIC FLOW IF SERVICE A INTEGRATED INTO NADIN

TRAFFIC INBOUND TO WMSC

MESSAGE TYPE	CONCENTRATOR TO SWITCH		SWITCH TO WMSC		CHAR/MSG
	MSG/HR	Kb/SEC	MSG/HR	Kb/SEC	
NADIN I-TYPE II	780	.21	1,116	.3	120
SAS COLLECTION	290	.03	3,480	.38	48
AREA A COLLECTION	19	.002	228	.05	48
SAS REQUEST	229	.015	2,740	.19	30
LOW SPEED REQUEST	23	.002	278	.02	30
TOTAL	1,341	.259	7,842	.94	

TABLE 2-4b NADIN-WMSC TRAFFIC FLOW IF SERVICE A INTEGRATED INTO NADIN

SECTION 3

BASIS OF SERVICE A - NADIN INTEGRATION STUDY

The analysis carried out in this report is based on an understanding of Service A, NADIN, their current structures and their future evolution. In this section, specific background relating to design, cost, performance and traffic is reviewed and a number of fundamental observations are made on which later analysis rests.

3.1 BASIS FOR DESIGN ALTERNATIVES

The selected design alternatives described are based on an understanding of the Service A environment in the 1980's as well as on the structure of NADIN as defined in the NADIN specifications. The non-NADIN alternative - Alternative 1 - refers to the meeting of Service A communication requirements by continuing the use of point-to-point and multipoint lines to the WMSC. The Service A circuits and nodes on which the design is based and on which the NADIN alternatives also depend are described below in Section 3.1.1. In addition, the NADIN alternatives for Service A are based on use of the NADIN backbone as prescribed in the NADIN Specifications, summarized in Section 3.1.2.

3.1.1 The Service A Environment - Current and Future

A description of telecommunications facilities is necessary in order to be able to adequately address the continuing use of the current means of communications with the WMSC i.e. point-to-point and multidrop lines. The 1982 telecommunications facility environment can be best addressed after a description of the current facilities.

3.1.1.1 Current Facilities (1980)

Since the Modernized Weather Teletype Communications System (MWTCS) is a centralized system, all circuits eminate from the WMSC in Kansas City to the users in the conterminous United States (CONUS), Alaska, San Juan, and Hawaii. The circuits of interest are classified and described as follows:

- Area Circuits - Half Duplex 75 bps multipoint teletype circuits designated to meet the routine distribution requirements of FAA and NWS users. There are presently forty (40) FAA and eighteen (18) NWS Area circuits in CONUS. In addition to these, there are five (5) FAA Area circuits to Alaska.

- Request/Reply - Half Duplex 75 bps multipoint teletype circuits which very roughly parallel the FAA Area circuits and enable government flight briefing facilities to obtain information not routinely distributed on Area circuits. There are forty (40) CONUS and four (4) Alaskan Request/Reply circuits.

- Supplementary Circuits - Full Duplex 75 bps point to point teletype circuits that allow high activity FSS sites unrestricted access to Request/Reply data. There are presently sixty-eight (68) circuits in this category which are all being displaced by SAS circuits.

- ARTCC Circuits - Full Duplex 75 bps point to point teletype circuits to twenty one (21) ARTCC's (CONUS and Alaska) used for Request/Reply, receipt, and transmission of certain flight related weather information.

- SAS Circuits - Full Duplex 2400 bps multipoint circuits used exclusively for SAS FSS sites. Currently over 90 sites installed and by December 1980, 149 sites will be connected to the WMSC by eighteen (18) circuits.

Typical Area A and Request/Reply circuits are shown on Figures 3-1 and 3-2 respectively. Table 2-1 reflects the number of circuits by category and general geographic distribution of these FAA circuits while Table 2-2 reflects the existing NWS circuits. The NWS circuits are shown because they contain some FAA users. Table 2-3 shows the degree that multiplexing is used for areas of high user concentration while Appendix B shows the specific geographic area covered by the area and Request/Reply circuits.

3.1.1.2 Future Facilities (1982)

By 1982 the environment will have evolved dramatically from the 1980 circuit environment. All SAS circuits will be in place as reflected in Appendix B. It is assumed

that the NWS users will have left the system for AFOS. As shown on Figures 3-1 and 3-2 both the SAS and AFOS will cause many stations to leave the Area and Request/Reply circuits. Also, FAA users that are now on the NWS Area circuits will be added to the Area and Request/Reply circuits as the NWS circuits will be assumed to be decommissioned. It is not clear what form the Area and R/R circuits will have in 1982 as some areas may not have enough users to support a circuit and consolidations will undoubtedly result.

3.1.1.3 Future Facilities (1983-90)

For alternative analysis future facilities will be taken as (1) what exists now (teletype and SAS circuits from the WMSC to local users with a limited amount of multiplexing) and (2) teletype and SAS circuits to the ARTCC NADIN concentrator (for connectivity to the WMSC).

3.1.1.4 Nodal Population Determination

A current nodal population would be of dubious value because of the rapid state of flux this population is undergoing now (Leased Service A implementation) and in the near future (AFOS). The objective is to build a time-phased representative population that will exhibit a reasonable insensitivity to change. Cost and performance calculations will be based upon this population within the context of the strategic assumptions. Therefore, in order to structure this population the following strategic assumptions are invoked:

(1) 1982 is the lower time bound for this study

(2) 1990 is the upper time bound for this study

(3) The 1982 to 1990 population will change due to the incremental implementation of FSAS

The 1982 configuration will differ from the current situation in the following respects:

- All Leased Service A Stations will be implemented deleting 75 bps terminals at these sites from existing Area A and Request/Reply circuits. These nodes will still be present but will exhibit different characteristics.

- FSAS will have implemented nineteen Model 1 AFSS's.

- AFOS will be implemented in some form and NWS facilities such as WSFO and WSO's will be absent from the nodal population.

The population through 1982 to 1990 will decrease as FSAS is implemented. An assumption is made that as an SAS site is displaced by an AFSS, the SAS equipment will displace low speed 75 bps terminals at another site.

3.1.1.5 <u>Nodal Population By Year</u>

<u>1982</u>

The 1982 population is constructed from two sources: the NADIN database and a list of existing and proposed Leased Service A sites. The NADIN database was created by NAC under previous contract and it represents a combination of the TELCOM and TSC data bases. A circuit by circuit examination of the Area A and Request/Reply circuits revealed the following:

- A small percentage of the stations on FAA Area circuits are NWS stations.

- A small percentage of the stations on NWS Area circuits are FAA stations.

- A small percentage of the stations on FAA Request/Reply circuits are NWS stations.

Because of AFOS implementation the NWS facilities on FAA Area and Request/Reply circuits are not included in the nodal population. Conversely, the FAA facilities on NWS Area circuits are included in the nodal population. The only exception to this is that combined NWS and FSS facilities are not deleted from the population. The dichotomy of FAA facilities in the population are FSS's and all others (such as TOWER, TRACON, TRACON/TOWER etc).

1983-1990

As previously articulated, FSAS implementation will result in a decline in the 1982 nodal population. This decline, however, affects only the FSS portion of the population and does not affect other FAA facilities. Figure 3-3 displays the year by year population for 1982 through 1988. Only the Area A, SAS, and manual sites are taken as part of the nodal population.

3.1.1.6 Nodal Characterization

There are three types of nodes present in the nodal population: stand alone terminals, cluster controller terminals, and a processing node. The low speed terminals are categorized as stand alone with each terminal presenting an interface point for the network while the SAS terminals are homed to a cluster controller which is taken to be the network interface point. The WMSC is the only processing node in the nodal population.

Detailed descriptions of the various node types and their applications are included in Appendix A.

3.1.2 The NADIN Alternative for Service A

Certain features are assumed to be common to any network design to be used for Service A integration into NADIN. The first is that all Service A nodes under consideration (Area A, Request/Reply, SAS and ARTCC) would be served by single function local circuits (Area A, Request/Reply, SAS and ARTCC) terminating at a NADIN concentrator. For example, all Area A nodes in the same Air Route Traffic Control Center Region would be served by circuits exclusively serving these Area A nodes and none other. Similar circuits would be designed for Request/Reply and Leased Service A, i.e. each circuit serves only one class of terminal all of which are in the same ARTCC region, although in a region more than one circuit of a given type might (and usually would) exist.

Traffic between the WMSC and these remote nodes would flow through the appropriate NADIN Switch to the appropriate NADIN concentrator and on to the local circuit. All polling of local Service A circuits would be conducted by the NADIN concentrators. Within this framework performance analysis was used to determine the constraints for the number of terminals per multipoint line for each class of circuit.

The objective in the design of the NADIN alternatives was to obtain delays which were acceptable as well as broadcast performance which was at least as good as the current Service A broadcast, while continuing to meet the NADIN specified performance for NADIN I traffic. Furthermore, certain functional restrictions were observed in the design process. Specifically, the NADIN concentrators and switches would not perform weather processing but rather would forward messages to or from the WMSC and its ultimate Service A users. The only deviation from this principle is that the switches will duplicate broadcasts as needed for forwarding to ARTCC's with multiple SAS or Area A circuits. Another guiding assumption was the principle of minimizing software and procedural modifications at the WMSC, since this facility is viewed as heavily burdened and having an uncertain future.

3.2 BASIS FOR COST COMPARISON

NADIN and non-NADIN alternatives were costed and reduced to a single present value cost (Appendix E). These projected costs were based on the following assumptions:

- Network design and node population as described in this report.
- WMSC software enhancement costs as described in this report (integration at time of WMSCR will reduce or eliminate some of these costs).
- NADIN I implementation expenses are considered as a sunk cost.
- Continued Availability of Telpak Rates (although relative rank of monthly recurring cost will be the same for most tariff structures).
- Modem leasing for SAS circuits.
- Modem purchasing for any other modems required.
- D1 conditioning needed for 9600 b/s lines.
- Western Union Reconfiguration charge for SAS will be collected (as explained in Appendix A).
- No salvage value for 4800 b/s modems (used on NADIN trunk circuits) displaced by 9600 b/s modems.
- Interexchange mileage charge (IXCM) taken to be same as current system for all alternatives.
- Hardware costs such as Area A teletypes are considered sunk.

Cost details are provided in Section 4.2. However, it should be noted that projected costs for Service A under the present system are based on the assumption that today's circuits will be reconfigured (see Section 4.3) using an optimization algorithm such as NAC's network design tools. If this reconfiguration is not carried out, then Service A costs without NADIN will be higher than estimated.

3.3 Basis for Performance Evaluation

The NADIN alternative for Service A is analysed in two parts, the first is the local access segment consisting of the remote DTEs such as Area A terminals served by multipoint lines terminating at the NADIN concentrators while the second is the network starting at the concentrator, through the switch and ending at the WMSC access port. Delays on the two parts of the system are determined in distinct but interrelated modeling analyses. End-to-end delays are taken to be the sum of the individual link delays.

The operation of the network is assumed to be in accordance with NADIN specifications for switch-concentrator and WMSC-switch links while the local access lines are assumed to continue as nearly as possible with current Service A protocols. These procedures are summarized below.

3.3.1 Switch Operation

The NADIN specification describes the functions to be performed by the switches and leaves the implementation details to the contractor. Nonetheless, a more detailed discussion of the operation is called for, since an implementation consistent with the specification may still result in unacceptable delays for short messages at the times of Service A broadcast.

One possible description of the switch operation is given, consistent with the design constraints in the NADIN specification, and is followed by modifications which make NADIN accommodate long broadcasts without adverse influence on short messages. The main change necessary in the switch design philosophy is to achieve the continuity of messages by providing additional buffer space at the concentrators rather than dedicating the switch attention to a message once its transmission is started. Other implementations and modifications are possible based on the same design criteria and should lead to similar results.

The following contraints on switch operation are given in the NADIN specification:

- Continuity of messages: For low-speed terminals which do not have the capability to reassemble the frames of a message, the interframe delay shall not exceed the time it takes to transmit one character, making the delay imperceptible to an operator.

- Flow control between switch and concentrator: The switch will not send a frame to a concentrator until it receives a message indicating that the output port to which the frame is destined is free or about to be free. This procedure prevents frames from arriving at the concentrator faster than they can be retransmitted over a low- or medium-speed output line.

- Switch output priorities: The switch has four levels of internal priorities and messages are queued for output according to these priorities.

- Link priorities: Once messages are queued for output they are transmitted according to two levels of priority. The first link priority is the same as the first internal priority. The second link priority is assigned to messsages of internal priorities 2, 3, and 4.

In addition to the above constraints, it is evident that the switch operation must be such that the switch-to-concentrator line is not idle if messages are available. Together with the necessity for continuity of messages and flow control, this means the following: if a message is composed of 3 frames and if it is selected for output, the switch will send only the first frame (flow control) and wait for permission from the concentrator to send the next frame. Instead of staying idle, it will then bring for output another message (destined to a different output port) and send the first frame. The switch will therefore service as many ports as needed to keep it occupied, interspersing their frames. Also, the switch will bring in a new message for output only if no extra frame from messages currently transmitted can be sent and therefore the constraint on interframe delay will be automatically satisified most of the time. Figure 3-4 represents the switch mode of operation, including the effect of priorities. On the left, messages ready for output are stored in some form of mass storage (such as on disk). On the right, messages in the output buffer are

being transmitted, sharing the switch-to-concentrator line on a frame-by-frame basis. The next frame to be transmitted is chosen round-robin (asynchronous time division multiplexing) with the exception of messages with the high link priority which are always given precedence (these constitute a very small portion of all messages). The transfer of a message from the disk storage into the buffer occurs only if there are not enough frames to keep the switch-to-concentrator line continuously busy.

The switch service discipline just described satisfies all the constraints given in the NADIN specification and is therefore one admissable representation among several switch designs based on the specification. However, this service discipline can produce unacceptable delays for short message traffic of Priority 2 or 3 because of blocking by broadcast messages (Priority 4). Specifically, if a Priority 3 message arrives in the Priority 3 queue when three medium-speed output buffers have just been loaded with 16-frame broadcast messages, the switch will be busy sending the three 16-frame messages. Since additional messages are brought to an idle output port buffer only if the switch does not have enough frames in other buffers to keep it occupied, the Priority 3 message is forced to wait in its queue until the completion of servicing of the broadcast messages already in progress. Even assuming the Priority 3 message arrives at its queue on average in the middle of this monopolization, the blocked message will still experience an 11 second delay with a 4.8 kb/s line from switch to concentrator. Such a scenario would be likely during the hourly SA broadcast, for example.

One solution to this blocking is to increase the line speed of the switch-to-concentrator link. However, the delays are so long that line speed would have to be increased as much as 50 Kb/s. A more economical approach is to modify the switch service discipline as interpreted above from the NADIN specification, in such a way as to make service more even handed.

The modification in the switch service discipline consists of transmitting one frame at a time from each message destined to an output port which is idle, even if other messages already being transmitted could keep the switch-to-concentrator line continuously busy. In Figure 3-4 this means that on the right, and for each output port at the concentrator, there is a buffer space containing a message destined to that port, if available, regardless of the presence of other messages in the output buffer. Clearly, this remedies the blocking of messages of Priority 1, 2, and 3 by broadcasts of Priority 4, since the delay imposed by broadcast messages is now the time to transmit one to three frames, rather than 16 to 48 frames.

The modified switch discipline outlined above will not in itself ensure the continuity of messages, as previously mentioned, since the switch may send several frames destined to different ports before returning its attention to a message under transmission. Rather, the continuity of messages can be ensured by a "window" mechanism. The window is a buffer space at the concentrator which can accommodate two or more frames destined to a given output port. Therefore, the switch can send a frame to a concentrator output port even if the transmission of the previous frame to the same output port is not completed. As a result, a delay between two frames will be perceived at the receiving end only if the time taken by the switch to give its attention to the last frame, plus the time of transmission over the switch to concentrator line, exceeds the time taken to transmit the two previous frames over an output line at the concentrator. Clearly, this occurs with very low probability in the case of low-speed output lines. In the case of medium speed output lines, like the NADIN concentrator to SAS lines, the occurrence of interframe delays is inconsequential, since the SAS controller has the processing ability to reassemble frames into a complete message before delivery to the user. The only case which therefore deserves some attention is the case of unbuffered medium speed output lines (e.g., 1200 b/s). If interframe delays occur frequently, they can always be reduced by increasing the size of the "window" at the concentrator.

It should be noted that at light to moderate traffic intensity the probability of an interframe delay is negligible, e.g., for NADIN I plus Service A traffic. A significant probability of interframe delays will occur only at high traffic intensity. Furthermore, most currently projected NADIN traffic on these 1200 b/s lines is of single frame length.

It should be understood that in the above discussion, the allocation of buffer space for output messages at the switch or input messages at the concentrator, is dynamic. For example, if there are 16 output ports at the concentrator and a window size of 2 frames of 250 characters for each, it is not necessary to reserve 16 x 2 x 250 / 1000 = 8 Kbytes of memory for windows. Instead, a smaller memory space will be sufficient most of the time.

3.3.2 Concentrator Operation

In addition to its function as the NADIN entry point and exit point for messages to and from the remote DTEs of Service A, the NADIN concentrators will take over the polling function now conducted by the WMSC.

3.3.3 WMSC Operation

The WMSC will continue to operate under the NADIN alternative in essentially the same manner as currently. However, broadcasts will be packaged on an enroute area basis rather than on a circuit basis. For example, one copy of the Area A broadcast for the Area A nodes in the Memphis (ZME) enroute area will be sent to the Atlanta Switch where three copies of it will be forwarded to the Memphis Concentrator for distribution to the three reconfigured Area A multipoint lines in the ZME enroute area. In addition, the switch will send another copy of the Area A broadcast to the Memphis ARTCC terminal node (labelled in the node data base as ZME-Z).

3.3.4 WMSC-Switch Link

The addition of Service A traffic to the currently projected NADIN I traffic on the WMSC-to-NADIN switch links would overwhelm the 4.8 kb/s lines now planned for the NADIN-WMSC interface. In addition, broadcast to the medium-speed leased Service A and low-speed Area A circuits would essentially monopolize a single high speed link if a simple first-come, first-served single message queue is used for the WMSC-to-switch links. One possible approach is to introduce a more sophisticated service discipline with multiple queues to be served by a single high-capacity line. This approach would be feasible for a WMSC Replacement but is not realistic for the current WMSC. However, Alternatives 2.1 and 2.2 represent an approach which is possible for today's WMSC and also provides greater reliability if used for an eventual WMSCR. The demands of Service A and NADIN I are satisfied in the NADIN alternatives by establishing three physically separate links, two at 19.2 Kb/s full-duplex and one at 2.4 Kb/s full-duplex. These three links need not necessarily extend all the way to the switch as separate lines but could be multiplexed and carried on a 50 Kb/s wide band line as illustrated in Figure 2-5. The cost tradeoff between multiplexing with a 50 Kb/s line versus carrying the three circuits all the way to the switch is presented in detail in Section 4.2.

In Sections 4.3.2 and 4.3.4 performance for the various types of Service A and NADIN I traffic on the WMSC-to-switch link is analyzed, assuming the three separate line approach (multiplexed or not is irrelevant to the results).

The WMSC-to-NADIN switch link uses Category B, character-oriented data link control procedures point-to-point, as described in Appendix C and amplified in Appendix Z

of the NADIN specifications. In particular, these procedures call for messages to be segmented into frames of 240 characters maximum length, including framing characters. Maximum message size is 3,700 characters of ASCII Code. It is also assumed that both stations idle in the ready-to-receive state so that usually no establishment procedures are required.

3.3.5 Switch-Concentrator Link

Two classes of concentrators are distinguished: the average concentrator is one with 3 SAS ports, 3 Area A ports, 3 low-speed Request/Reply ports, and one low-speed Z-port (ARTCC) in addition to the NADIN I ports. A large concentrator is one with 4 or 5 SAS ports. Since there are only 3 centers that fall into the large category, the primary focus is on analysis of the average center. However, the large center is also briefly discussed in Section 4.3.1.6.

As is shown in section 4.3.1, an average center is adequately served by a single 4.8 Kb/s full-duplex line from its NADIN switch; but, a large center requires a 9.6 Kb/s full-duplex line from switch to concentrator.

The switch-to-concentrator protocol is specified in Appendix Z to be the High-Level Data Link Control Procedures outlined in Appendix A of the NADIN Specifications. Messages from the switch to a concentrator are broken into frames of 250 charaters in the ADCCP format shown in Figure 3-5.

3.3.6 Leased Service A (SAS) Local Access

It is assumed that the NADIN concentrators will communicate with their SAS nodes via ANSI X3.28-2.7 protocol, using category A2 for message transfer from the concentrator to a remote node and using A4 for message transfer from the remote node to a concentrator (cf. FAA/NSS Performance Specification, January 19, 79-0015). The code is ASCII. The two procedures in this protocol are a select-broadcast procedure and a polling procedure. The poll procedure is used both for collection of data such as SAS and for Request/Reply. It is assumed that the bit error rate for the SAS 2400 b/s line is $P_B = 16.7 \times 10^{-6}$.

3.3.7 Area A Local Access

Broadcast to Area A nodes will be performed by the concentrator in essentially the same way as presently used by the WMSC as described in the FAA-ATS Data Communications manual.

Collection will be carried out by the concentrator which will poll each node using essentially the protocol now used by the WMSC in which a negative response by a terminal is indicated by 5 seconds of no response. If the station polled has a response, it sends — TEXT + 8 characters — or if collection is unscheduled, it prefixes transmission with time date group characters.

3.3.8 Request/Reply Local Access

Request/Reply nodes will be polled by the NADIN concentrator for possible input of requests. When a request is inputted to the concentrator, the concentrator will immediately forward it to the WMSC for processing. However, the concentrator will also resume polling as soon as it has received the end of the request from the R/R terminal.

There are two queues, one at the terminal for requests and one at the concentrator for replies.

3.3.9 Buffer Use at Switch

The results on buffer requirements at the switch which were presented in Section 2.3.5 are based on the analysis in Section 4.3.7.

3.4 TRAFFIC BASIS

The brief traffic summary in Section 2.4 is based on a detailed description of traffic in terms of message lengths, arrival times, sources, sinks and other characteristics. Service A traffic is all centralized either originating at or addressed to the WMSC. The dominant types of Service A traffic are the deterministic scheduled broadcasts and the stochastic request/reply traffic. In addition, the NADIN alternatives need to take into account the effect of NADIN I base traffic which is primarily short message stochastic.

The sources of information used as a basis for the traffic requirements were:

- FAA Directive 7110.80 Data Communications Handbook dated Jan. 1, 1979 Changes 1-4,
- FSAS documentation,
- WMSC Daily Report of February 29, 1980,
- WMSC Broadcast received at Leesburg FSS on January 21, 1980,
- Discussions with FAA personnel (AAT, NATCOM and Leesburg FSS),
- NADIN Specifications - Appendix Z.

A number of key assumptions were made in interpreting this traffic data for design purposes:

- Request/Reply traffic will grow on a per terminal basis approximately 20% over 1983-1990 period.
- Weather traffic (broadcast and collection) will not increase.
- Traffic will be scaled to reflect peak day and peak hour levels.
- Each SAS circuit in the <u>same</u> enroute area will receive identical broadcasts from the WMSC, consisting of approximately one-third of the corresponding national data base. Of course different enroute areas will receive different broadcasts.
- Each Area A circuit in the <u>same</u> enroute area as well as the ARTCC dedicated node will receive identical b[illegible]ts equal in size to the current average Area A broadcast. Each enroute area re[illegible]s its own distinct broadcast.

- Each KVDT connected to an SAS controller will generate requests equivalent to those by a Request/Reply low speed terminal. While the SAS cluster will contain a large local data base for request/reply query, no data is available as yet to indicate to what extent this will reduce request/reply traffic to the WMSC. This assumption is made to be conservative in performance evaluation and because of possible increased use of the request/reply capability due to the improved responsiveness of the new equipment (so called "Turnpike Effect").

- NADIN I base traffic is that listed in Appendix Z of the NADIN Specifications.

- Delays on the NADIN network must meet NADIN Specifications for both Service A and NADIN I base traffic.

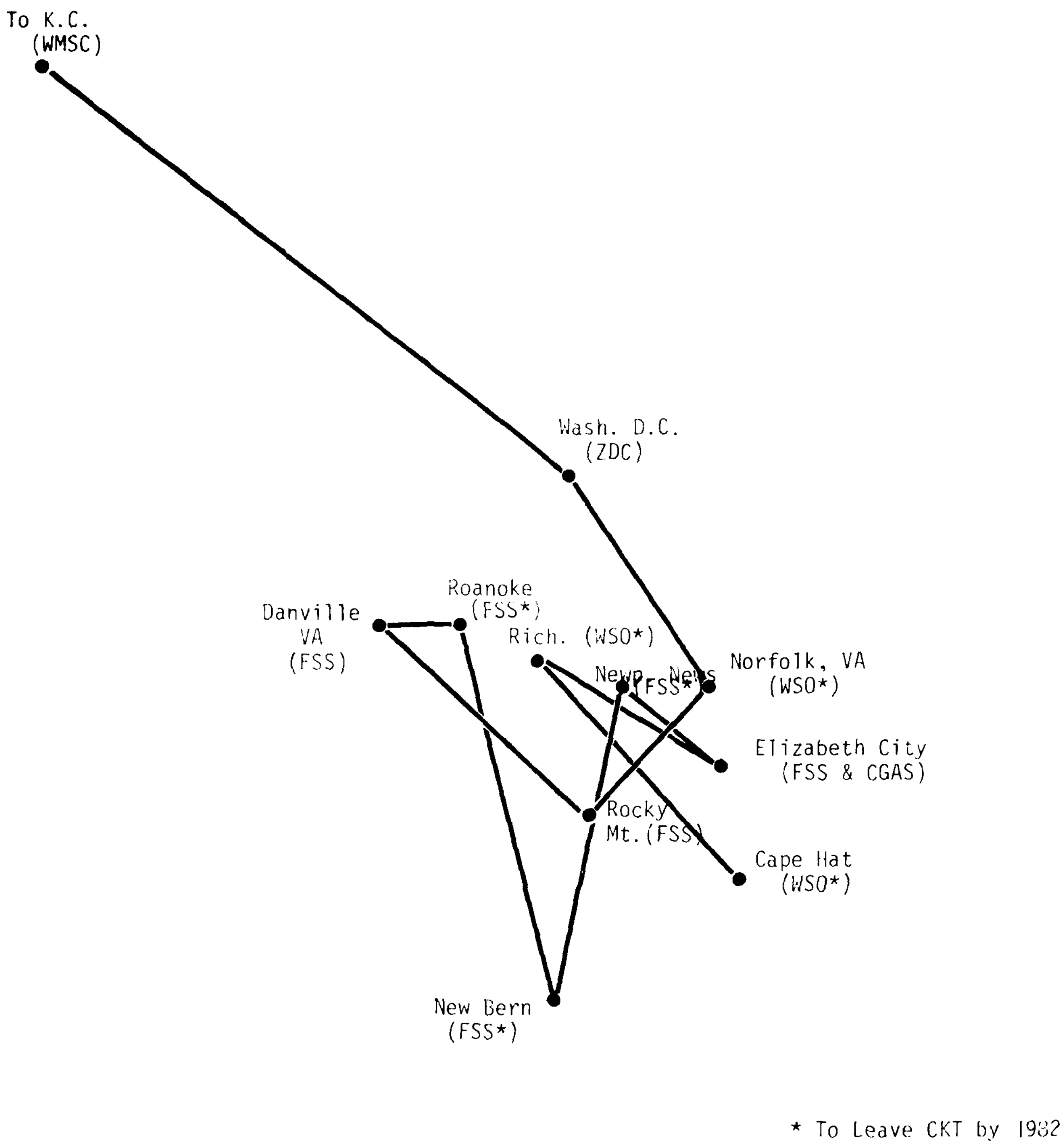
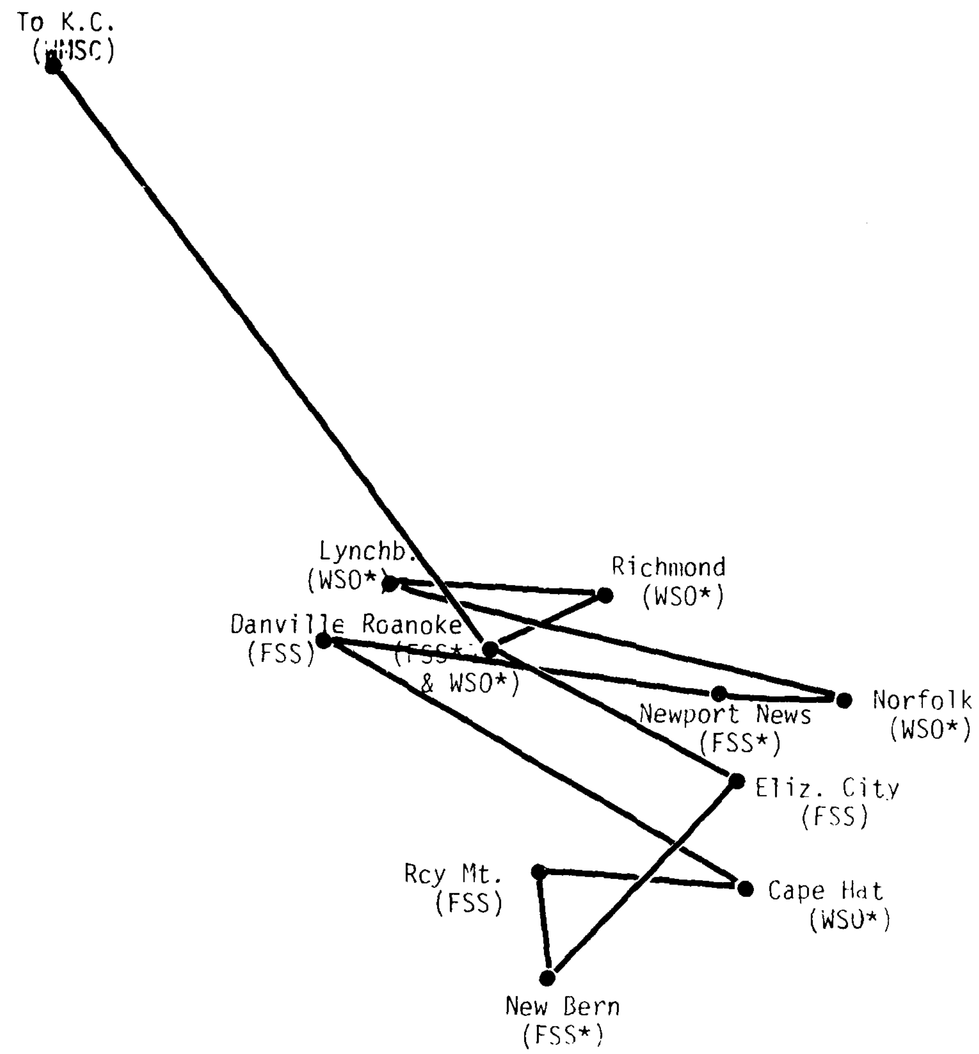


Figure 3-1: Area Circuit #7 GT8001-007



* To Leave Circuit by 1982

Figure 3-2: R/R CIRCUIT #7 GT8001-107

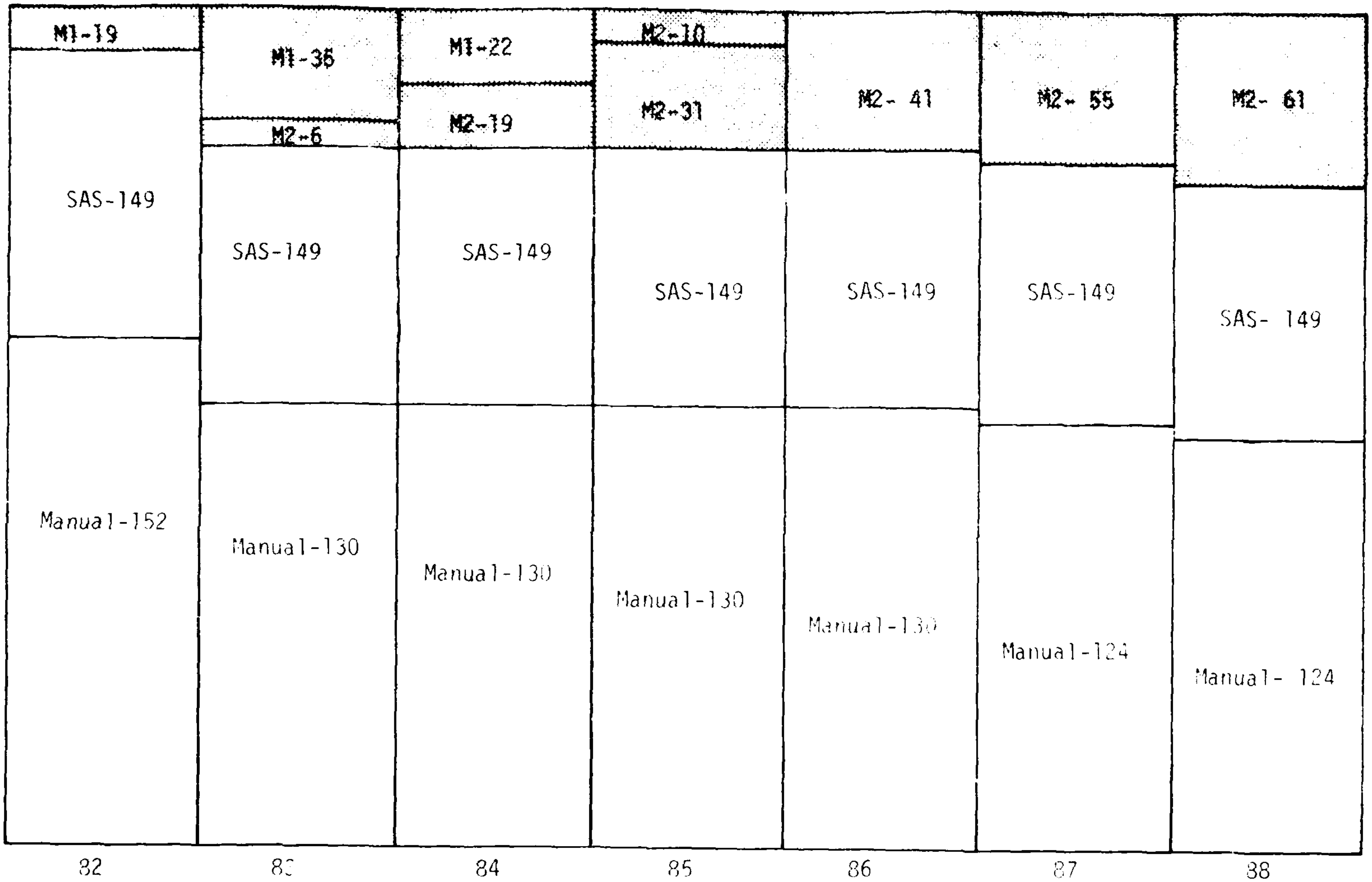


Figure 3-3: ASSUMED FSS NODAL POPULATION BY YEAR

AREA A R/R

FSAS

M1: Model 1 FSAS
M2: Model 2 FSAS
SAS: Leased Service A
Manual: Mostly M-[illegible]

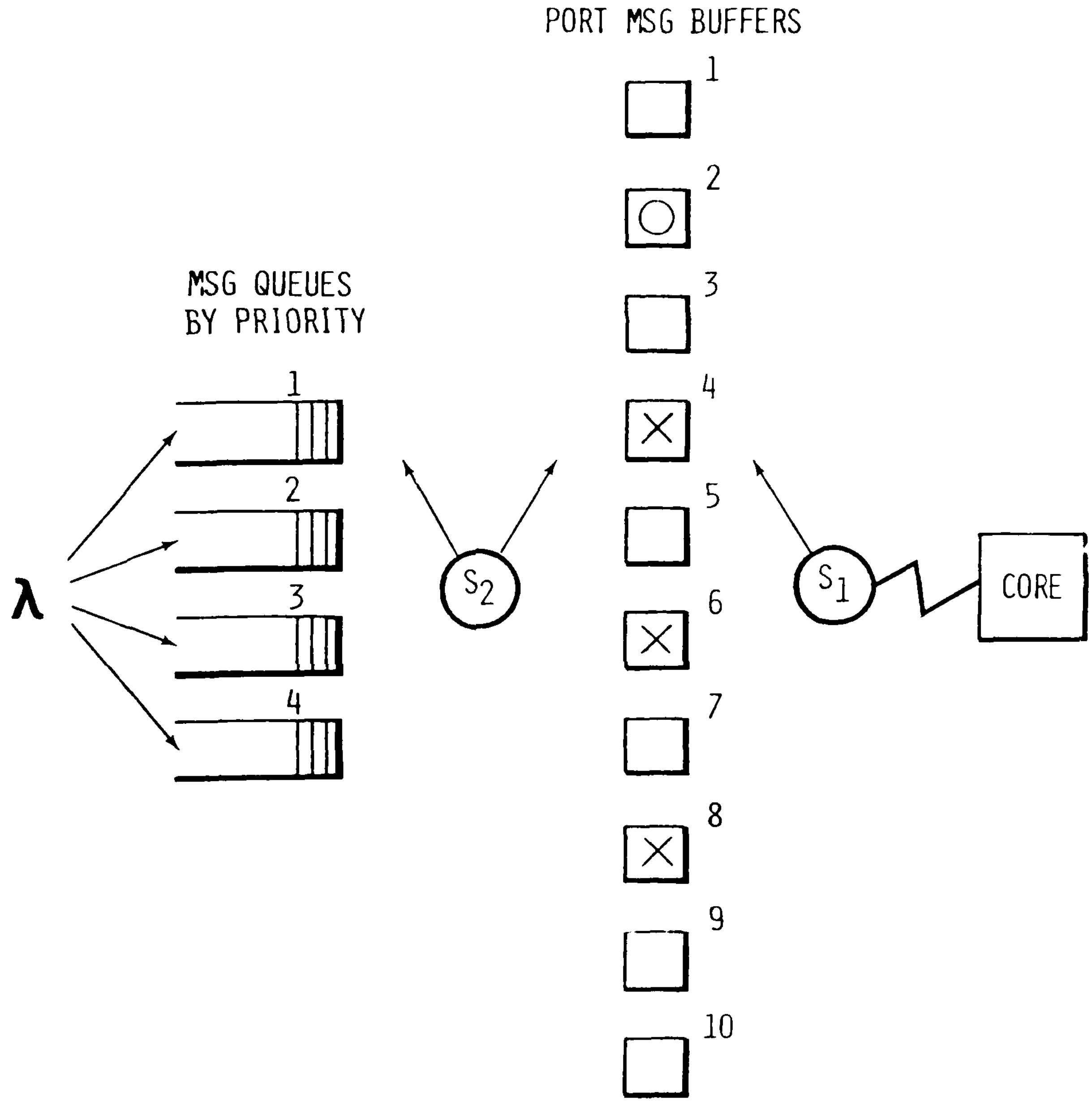


FIGURE 3-4: NADIN SWITCH FRAME SELECTION PROCESS

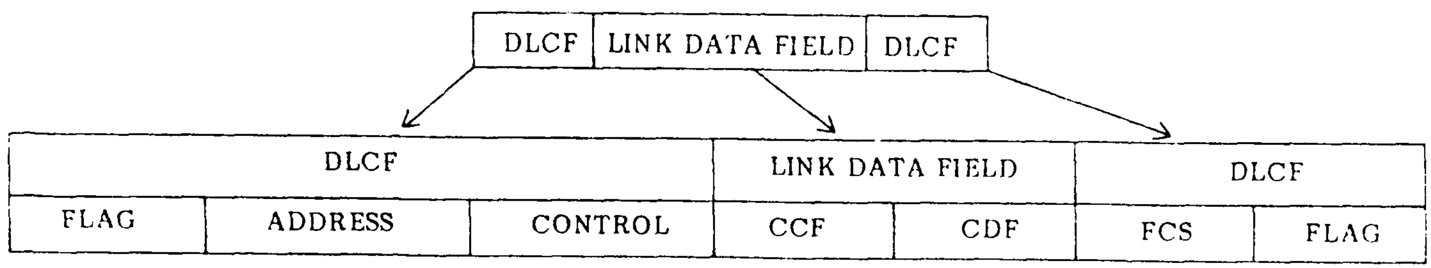


FIGURE 3-5: DATA LINK CONTROL FIELD AND
LINK DATA FIELD FOR NADIN BACKBONE MESSAGES

LOCATION	AREA A HALF DUPLEX	R/R HALF DUPLEX	SUPPLEMENTARY* FULL DUPLEX	ARTCC FULL DUPLEX
CONUS	40**	40**	65	20
ALASKA	5**	5**	1	1
HAWAII	1**	0	1	0
PUERTO RICO	0	0	1	0
TOTAL	46	45	68	21

* TO BE DISPLACED BY SAS

** INCLUDES SOME NWS USERS

Table 3-1:EXISTING MWTCS FAA TELETYPE CIRCUITS

LOCATION	NWS AREA HALF DUPLEX	NWS WSFO FULL DUPLEX	MILITARY RECEIVE ONLY
CONUS	18*	42	16*
ALASKA	0	4	0
HAWAII	0	1	0
PUERTO RICO	0	1	0
TOTAL	18	48	16

* INCLUDES SOME FAA USERS

Table 3-2: EXISTING MWTCS NWS TELETYPE CIRCUITS

LINE FROM KANSAS CITY TO:	NO. OF CIRCUITS MULTIPLEXED:		
	AREA	R/R	ARTCC
OAKLAND	6*	5	1
MIAMI	2	2	2
JFK	1	1	0
ISLIP	2	2	0
ANCHORAGE	4	4	1
TOTAL	15	14	4

NOTE: SUPPLEMENTARY CIRCUITS NOT SHOWN AS THEY ARE BEING DISPLACED BY SAS.

* INCLUDES ONE CKT TO HAWAII

Table 3-3 USE OF MULTIPLEXING FOR EXISTING MWTCS TELETYPE CIRCUITS

SECTION 4

ANALYSIS OF SERVICE A ALTERNATIVES

Local access design tools, cost models, queueing models and traffic analyses are presented in this section to analyze the design, cost, performance and traffic characteristics of the Service A communication alternative both in NADIN and independent of NADIN.

4.1 DESIGN ANALYSIS

The NADIN alternatives described in Section 2.1 are based on the node population listed by ARTCC and by type in Appendices C and D respectively.

4.1.1 Local Access Design

The local access portion of the NADIN alternatives was designed first based on reasonable assumptions (consistent with NADIN Specifications) of the performance to be obtained from the NADIN backbone. Performance analysis for the various types of circuits, SAS, Service A, and Request/Reply was carried out with particular focus on the effect of the number of nodes/circuit on performance. Maximum values were chosen for nodes/circuit for each of the three types of multipoint lines, SAS, Area A and Request/Reply. These constraint numbers together with the population data base in Appendix C were used as inputs to NAC's network design software tool GRINDER. This algorithm designed a minimal cost local access line layout for each of the three types of circuits. These layouts were used in turn in obtaining local access performance, cost and backbone impact. The results of the local access design are summarized in Tables 4-1 and 4-2. The most notable results in the local access design is that the number of nodes/ckt in the most cost effective NADIN design is significantly smaller than the maximum number of nodes/line used as the constraint value. This shows that the NADIN concept makes cost/effective the use of circuits with fewer nodes/ckt than today's non-NADIN Service A multipoint lines with a resulting improvement in performance.

For SAS and Request/Reply circuits the choice of constraint number for nodes/circuit was based on analysis of delays for Request/Reply traffic. For Area A circuits the choice of maximum nodes/ckt was based on analysis of the time required to complete the time critical A1 scan for collection of surface observations (SAs) and other inputs.

4.1.2 Switch-Concentrator Links

Because each SAS circuit in an ARTCC region will receive a copy of the WMSC broadcasts from the NADIN switch, the traffic on a particular switch to concentrator link is heavily dependent on the number of SAS circuits in that concentrator's ARTCC region. In order to handle the large volume of broadcast for centers with more than three SAS circuits it was determined through the performance analysis in Section 4.3.1, that these large centers would require switch links of 9.6 Kb/s capacity instead of the NADIN I planned 4.8 Kb/s links. In particular, the backbone design was chosen so as to provide broadcast to the local SAS circuits at a rate approximately equal to the rate at which they could disseminate it to the individual SAS controllers.

4.1.3 WMSC-Switch Links

As described in Section 2.1.2, it is deemed inappropriate to propose a major software development effort for the WMSC. Therefore, the concept of separate physical channels for SAS broadcast and collection, for Area A broadcast and collection and for NADIN I and Request/Reply traffic is proposed. The choice of 19.2 Kb/s lines for SAS broadcast is based upon the need to complete scheduled broadcast and collection according to the Service A hourly schedule. This is accomplished by assuring that broadcast is delivered to the switches at essentially the same rate at which the switch can forward it to the concentrators while still handling demands of other traffic. Specifically to keep the switch working up to its full capacity for serving SAS buffers, a throughput of at least 13.2 Kb/s is required on the WMSC-Switch SAS broadcast channel. A similar philosophy leads to the choice of the Area A channel at 2.4 Kb/sec.

The channel for WMSC-Switch Request/Reply and NADIN I traffic was sized to insure average delays of less than .5 seconds. Use of a 9.6 Kb/s channel on the other hand, would lead to a traffic intensity close to one causing very significant (5 sec) queueing delays.

The choice of NADIN Alternative 2.1 over Alternative 2.2 is based solely on cost as performance is presumed to be virtually identical for both.

4.2 COST ANALYSIS

This section contains a breakdown into individual components of the costs presented in Section 2.2 as well as a discussion of the costing methodology.

4.2.1 NADIN Costs

Local Access Costs for the four types of circuits Leased Service A (SAS), Area A, Request/Reply and ARTCC terminal nodes were determined individually using the NAC design tool GRINDER and the Telpak tariffs. Then the costs of NADIN enhancements both fixed and recurring were determined as well as WMSC-NADIN costs. All these costs were combined to form a single total monthly recurring charge and a single total one-time cost as shown in Table 4-3. These two totals were then used to determine total present value costs over various life cycles. The NADIN monthly recurring costs, exclusive of the WMSC-Switch links, are shown in Table 4-4. NADIN one-time costs exclusive of the WMSC-Switch Links are presented in Table 4-5 while Table 4-6 displays all of the WMSC-Switch costs both monthly recurring and one-time.

One of the charges mentioned in Table 4-5 requires further explanation. The Leased Service A system is provided by Western Union through DECCO. The tariff for this service is unique in that the tariff which includes the basic complement of equipment has embedded within it, a fractional cost for the telecommunications facility (leased line). The termination liability, ostensibly there to protect Western Union's equipment investment, is quite considerable. It is assumed that any circuit reconfigurations would allow Western Union to collect the entire site liability. The liability is three years from date of acceptance on a per site basis. As installations started in the fall of 1979 and are to end in the fall of 1980, a linear liability is assumed from January 1980 to January of 1983. Figure 4-1 reflects the liability assumption. It is not known if Western Union would want to collect the liability for a circuit reconfiguration, but it will be assumed that they will.

4.2.2 Method for Calculating Non-NADIN Costs

The Service A node population which will exist in 1982 is not the same as that now in existence. Leased Service A equipment is in the process of being installed, while a number of low-speed terminals are being displaced including Area A and Request/Reply. As terminals are eliminated, today's multipoint circuits will be reconfigured in an as yet unknown manner. To establish the monthly costs of Service A in 1982, the following procedure was employed. Using the node population projected for 1982 in Deliverable C1, optimal line layouts for each of the current circuits were determined. This method is best explained by focusing on a single example, Area A, although the same method was used for

Request/Reply and SAS. (The 19 circuits from each ARTCC (except ZKC) to the WMSC are costed in a simpler manner discussed subsequently.)

The 1982 Area A terminal population was partitioned into 40 circuits by choosing a "central node" corresponding to the current (1980) location of the 40 CONUS Area A circuits. In each partition, the terminals were optimally connected via multipoint lines to the "central" node using NAC's network design tool GRINDER. Each "central" node was then connected via a point-to-point line to the WMSC. The resulting Area A simulated network was costed using the Telpak tariff and the GRINDER tools. This procedure provides an estimated cost for continuation of Area A circuits under the current non-NADIN philosophy. However, actual costs of the non-NADIN alternative will be somewhat higher if an algorithm for optimizing local line layouts is not used in carrying out necessary reconfigurations as terminals leave the population with the completion of leased Service A implementation.

Figure 2-1 illustrates a typical non-NADIN Area A circuit (#23) as simulated for the cost model.

A similar partitioning scheme was used for estimating the cost of the Request/Reply and leased Service A circuits. Finally, the ARTCC nodes were costed by configuring them into a star-shaped network centered at the WMSC and using NAC software tools to calculate line costs.

Table 4-7 shows the costs of the various types of Service A circuits, which are all monthly recurring costs. The costs for a NADIN independent Service A will be slightly lower if multiplexing from Oakland and a few other current locations is employed. It is difficult to determine the precise cost savings to be gained through multiplexing because of the sharp reduction in the low speed terminal population which is occurring. However, the saving would probably not be greater than 2%. In many cases, this cost reduction could make the non-NADIN alternative only very slightly more cost effective than shown in Table 2-2.

4.3 PERFORMANCE ANALYSIS

In this section the performance results reported in Section 2.3 are derived. Of particular interest are the Request/Reply Delays and the broadcast and collection characteristics.

NADIN end-to-end delays are obtained by summing the individual link delays, for example, the delay for a request from Remote DTE to WMSC is given by

$$\text{Delay} = D_1 + D_2 + D_3$$

where

D_1 = Delay from remote DTE to Concentrator

D_2 = Delay from concentrator to Switch

D_3 = Delay from switch to WMSC.

NADIN Request/Reply delays are listed in Table 4-8.

Non-NADIN delays are assumed to be equal to the NADIN local access delay for the corresponding number of nodes per circuit.

Broadcast and collection minutes for the NADIN alternative are found by taking the maximum value of completion time on the three links, WMSC-Switch, Switch-Concentrator and Concentrator-Remote Node shown in Table 4-9.

Delays for stochastic traffic and peak throughput for deterministic traffic are obtained in this section. Switch buffer demand is also derived.

4.3.1 Switch-Concentrator Delays

The most complex of the modeling efforts required in this study were those of the switch operation and specifically traffic flow from switch to concentrator.

The switch-to-concentrator analysis is based on the modifications described in Section 3.3.1. For each concentrator there are queues corresponding to each Service A concentrator port so that for an average concentrator there are 3 SAS queues, 3 Area A queues, 3 Request/Reply low speed queues, and 1 Z ARTCC queue in addition to the 11 NADIN Level I ports listed in Appendix Z of the NADIN Specifications.

For each concentrator port it is assumed that there is buffer space at the concentrator for two frames addressed to one or more terminals on the corresponding local circuit. The concentrator informs the switch of availability of buffer space for frames from the switch. Each port has traffic of mainly a single priority level. This makes it possible to treat Priority 2, 3, and 4 messages without distinction in the model. Priority 1 traffic can be neglected in examining the behavior of other types of traffic because it accounts for less than .002 of total traffic.

The switch will be viewed as cyclically sampling the output queues corresponding to its associated concentrator ports. If a frame is present in a sampled queue and if buffer space for it is available at the concentrator, then the switch sends the frame to the concentrator for forwarding to the appropriate node or nodes. The procedure is represented schematically in Figure 4-2. In determining the performance which the switch will provide for Service A, the Level I NADIN traffic (which accounts for 26 percent of the newly combined traffic) will be considered as uniformly distributed over time and accounted for via an overhead factor. On the other hand, to analyze the impact of Service A on NADIN Level I traffic the Level I ports will be individually distinguished from the uniform "background traffic" and added to the queue model described in Figure 4-2. The details for NADIN I are provided in Section 4.3.1.5.

The switch-to-concentrator protocol is specified in Appendix Z to be the High-Level Data Link Control Procedures outlined in Appendix A of the NADIN Specifications. Messages from the switch to a concentrator are broken into frames of 250 characters in the ADCCP format shown in Figure 3-5.

The Control Data Field contains the NADIN header and all the data portion of the message. Most information included in a NADIN header need not be repeated on second and subsequent frames of a multiframe message. The number of overhead characters in a frame also depends on whether or not the message has a multiple address or single address. The approximate number of data bits for each of the three types of frames is shown below:

- first frame of single address message — 1600 data bits;
- first frame of multiple address message — 1400 data bits; and
- second and subsequent frames of any message — 1800 data bits.

The time T_{fr} required to transmit a single frame of 250 characters from switch to concentrator is given by:

$$T_{fr} = 2000 \bullet F \bullet E \bullet L_1/S$$

where

F = flow control overhead factor assumed to be 1.03

S = line speed (bits/sec)

E = frame error factor = 1.02 (explained below)

L_1 = overhead due to Level 1 NADIN traffic (explained below)

The factor E is derived from the equation

$$E = (1-P_E)^{-1}$$

where P_E is the probability that a frame is received in error. P_E in turn is given by:

$$P_E = 1-(1-P_B)^{2000}$$

It is assumed that P_B the bit error rate is 10^{-5}.

The factor L_1, the overhead due to Level I NADIN traffic (to be used for analysis of Service A performance only) is line-speed dependent and is defined by:

$$L_1 = \left(\frac{S}{S-S_1}\right)$$

where S_1 is the throughput rate for Level 1 traffic which equals 328 b/s. For a 4.8 kb/s line

- L_1 = 1.07 and
- T_{fr} = .47 sec.

Another parameter important in the switch-to-concentrator analysis is the rate at which frames can be absorbed by the various types of local circuits. The rate determines the availability of buffer space at the concentrator. The absorption time A_1 for the average SAS medium-speed circuit is 1.46 sec/fr. while for the low-speed circuits (Area A, R/R, and Z) the time jumps to 27 sec/fr.

4.3.1.1 SAS Broadcast — Switch to Concentrator

During an SAS broadcast period the SAS queues at the switch are assumed occupied constantly. The time required to deliver an SAS frame to the concentrator is estimated by bounding the service time using a worst case/best case approach. The worst case results are Mean Service Time per frame:

$$MST_{fr} = 1.65 \text{ sec./fr.},$$

throughput rate Th:

$$Th = 1.1 \text{ Kb/s.}$$

The time to complete the hourly SA broadcast under worst case assumptions is 2.46 minutes while the total broadcast time per hour is 8.66 minutes. The best case results are:

$$MST_{fr} = 1.54 \text{ sec/fr.}$$

$$Th = 1.2 \text{ Kb/s.}$$

The best case completion time for the SA broadcast is 2.3 minutes/hour, while total broadcast time per hour is 8.06 minutes.

These results are obtained in Appendix G.

4.3.1.2 Area A Broadcast — Switch-to-Concentrator

The rate at which the switch services frames for Area A broadcast is essentially determined by the rate at which buffer space becomes available at the appropriate concentrator output port. Hence, the service time is approximately 27 seconds when medium-speed broadcast is not in progress and 28.5 seconds during medium-speed broadcast. The average 27.75 seconds is used for MST per frame. Based on the traffic values in Table 4-10, this means that the time required for the hourly SA broadcast to Area A circuits is approximately 11.7 minutes while total hourly broadcast requires 42.3 minutes.

Delays for Area A broadcast are not of serious concern because only the first frame of a multi-message broadcast contributes to the users' observed delay. The likely delay under

worst case conditions would be one-half short cycle (as described in Section 4.3.1.1) plus one-half time required to send three Area A frames:

$$\text{Average Delay} = (.5)(1.41) + (.5)(1.41) = 1.41 \text{ seconds.}$$

4.3.1.3 Replies to SAS Circuits

Switch-to-concentrator handling of SAS Reply frames is also modeled on a worst case/best case basis or more accurately on a busiest vs. normal basis. The worst case delay for a reply frame is .66 sec. while the best case delay is .60 sec.

$$\text{Delay} = MST_{fr} + W_q$$

where

MST_{fr} = mean time to send an SAS frame which is at head of queue;

W_q = mean wait in queue for service.

In the worst case:

MST_{fr} = .53 sec.

W_q = .13 sec.

In the best case:

MST_{fr} = .49 sec.

W_q = .11 sec.

The results above are derived from two M/M/1 queue models (see Kleinrock), one for worst case and one for best case. In both cases, the conservative assumption is that all Area A queues are occupied. As noted in Section 4.1.5, Request/Reply traffic flows on local SAS

circuits only when broadcast is not occurring. The assumption is made, therefore, that all SAS reply traffic occurs during the approximately 50 minutes of the hour in which there is no SAS broadcast.

In both cases, the 3 SAS queues associated with an average center are treated as a single queue. Interarrival times are assumed exponential with mean equal to the sum of the three individual arrival rates. The service times for both cases are assumed to be exponentially distributed with mean service rates described below. Care is required to derive an appropriate concept of mean service rate in this model.

The details are in Appendix G.

4.3.1.4 Replies to Request/Reply Low Speed Circuits

Switch-to-concentrator handling of low-speed replies can also be modeled on a worst case/best case basis using two M/M/1 queues. The worst case delay for a low-speed reply frame on this link is 1.4 seconds while the best case delay is .6 seconds. As in the preceding section, delay is given by:

$$\text{Delay} = MST_{fr} + W_q$$

where

MST_{fr} = mean time to send a R/R low-speed frame at the head of the queue;

W_q = mean wait in queue.

In the worst case:

MST_{fr} = 1.3 sec./fr.

W_q = .07 sec./fr.

In the best case:

MST_{fr} = .59 sec./fr.

W_q = .01 sec./fr.

These results are obtained by following an analysis similar to that in the preceding section. The three Request/Reply queues of the average center are treated as a single queue having Poisson arrival with mean λ = .04 fr./sec. This is determined by taking three times the mean arrival rate for a single low-speed Reply queue at the switch. The service time distributions are assumed to be exponential for both cases. The derivations of the mean service rates are discussed in Appendix G.

4.3.1.5 NADIN Level 1 Traffic: Switch-to-Concentrator

It is important to determine the effect on NADIN I traffic of adding Service A traffic to the NADIN switch-to-concentrator links. There are numerous types of NADIN I circuits, low-, medium-, and high-speed, handling various types of messages. However, all these diverse types can be modeled similarly. Because of the very low line utilization and the fact that all NADIN I low-speed circuits receive only short message (Type II) traffic, it is safe to ignore the very rare event in which a NADIN I frame (Type II only) is ready for transmission by the switch but cannot be sent because the local circuit's two-frame window at the concentrator is full.

To investigate the effect of Service A traffic on any one of the ten different categories of NADIN I switch output ports, proceed as follows: treat all NADIN I traffic other than the specific destination traffic being analyzed as overhead on the link from switch to concentrator. Then model the traffic in question as a single server queue with an appropriate service rate reflecting Service A usage of the switch. From Appendix G it is found that the average switch-to-concentrator delays can be conservatively estimated as:

FOT	1.2 sec.
Local DTE	1.2 sec.
Remote DTE	1.23 sec.
Area B	1.2 sec.
Military B	1.2 sec.

AFTN	1.2 sec.
Air B & Utility B	1.2 sec.
MAPS	1.23 sec.

Two users receive Type III traffic: International AFTN and the 9020 computer. The 9020 also receives Type II traffic. From Appendix G these average delays during a broadcast period to SAS and Area A are seen to be:

INT'L AFTN	1.4 sec.
9020 - TYPE II	1.34 sec.
9020 - TYPE III	1.43 sec.

[illegible] Switch to Large ARTCC Analysis

For centers with 4 or 5 SAS circuits, 9.6 Kb/s lines are required to keep delays to acceptable levels. Under Telpak tariffs, the additional cost of a 9.6 Kb/s line compared to a 4.8 Kb/s line will be for the modems only since line cost for each speed is $.56 per mile. The analysis determining performance levels is essentially the same as for 4.8 Kb/s lines. All performance is slightly better for a large center with a 9.6 Kb/s line compared to an average center with a 4.8 Kb/s line. For comparison, some representative performance parameters for a large center under various assumptions are shown in Appendix G.

4.[illegible] WMSC-Switch Analysis

The WMSC-to-NADIN switch link uses Category B, character-oriented data link control procedures point-to-point, as described in Appendix C and amplified in Appendix Z of the NADIN specifications. In particular, these procedures call for messages to be segmented into frames of 240 characters maximum length, including framing characters. Maximum message size is 3,700 characters of ASCII Code. It is also assumed that both stations idle in the ready-to-receive state so that no establishment procedures are required.

One of the key parameters in the performance analysis is the average time required to send one error-free frame of 240 characters from the WMSC to a NADIN switch. The time for a frame T_{fr} is given by:

$$T_{fr} = \frac{1920}{s} \bullet E$$

where

s = line speed in bits per second

E = Error Factor $= \frac{2}{1 - P_{EF}} - 1 = 1.04$

P_{EF} = probability that a frame is received in error = .019. The value of P_{EF} is computed from the bit error rate B_E, assumed to be 10^{-5} by the formula

$$P_{EF} = 1 - (1-B_E)^{1920}$$

The factor "2" in the formula for E reflects the fact that usually 2 frames are outstanding and would be retransmitted if the first receives Negative Acknowledgement (NAK).

The value of T_{fr} is .104 seconds for a 19.2 Kb/s line and .832 seconds for a 2.4 Kb/s line.

4.3.2.1 Broadcast to Leased Service A - Line 1

In order to insure timely delivery of the various scheduled and unscheduled Service A broadcasts to their eventual medium speed destinations, it is proposed that a 19.2 Kb/s full-duplex line from the WMSC to each switch be dedicated exclusively to this purpose (including collection of weather data from the same medium speed terminals).

This section discusses broadcast performance, deferring the discussion of collection of weather data to Section 4.3.4.1. Broadcasts are assumed to be segmented into messages of maximum size 3700 characters. Overhead reduces the number of data characters per message to approximately 3250. These messages are in turn divided into frames of 240 characters or an average of 15.5 full-length frames per message.

The time to send a broadcast message T_{msg} is now given by:

$$T_{msg} = (15.5) \bullet T_{fr} = 1.62 \text{ sec.}$$

where T_{fr} = 1.04 sec. (Section 4.1.2)

Using the traffic figures of Table 4-10, the total hourly SAS broadcast to the larger switch can be estimated at 268 msg/hr. while broadcast of surface observations contains 77 msg/hr. The completion times described in Section 2.3.6 are now easily computed:

- total hourly broadcast to SAS = $(268) \bullet (1.62)$ = 435 sec. or approximately 7.25 min;

- hourly surface observation (SA) broadcast = $(77) \bullet (1.62)$ = 125 sec. or approximately 2.1 minutes.

Delay in receipt of the start of broadcast from its initiation at the WMSC will generlly not be an important measure of broadcast peformance. However, for completeness the delay is included here. From the WMSC release of the first frame of a broadcast stream to the receipt of the last character of the initial frame at a NADIN switch the time elapsed is given by:

$$\text{Delay} = T_{fr} = .104 \text{ sec.}$$

4.3.2 Area A Broadcast — Line 2

Area A broadcast is broadcast traffic addressed to the low-speed Area A circuits (75 b/s). Inclusion of this traffic on the same physical line as medium-speed broadcast or Request/Reply traffic would lead to unacceptable delays and throughput rates in the absence of extensive software enhancements at the WMSC. Hence, it is assumed that all Area A broadcast (and collection) traffic between the WMSC and each NADIN switch is carried on a dedicated 2.4 Kb/s full-duplex line. The performance which results from this line selection is described below.

The time required for total broadcast for Area A circuits is easily computed using the traffic figures from Table 4-10 and the transmission time for a frame from Section 4.3.2. First, the time to send an error-free message is:

$$T_{msg} = (15.5) \bullet T_{fr} = 12.9 \text{ sec./msg.}$$

where

$$T_{fr} = \text{time to send one error-free frame at 2.4 Kb/s} = .832 \text{ seconds.}$$

The total Area A broadcast is assumed to be divided into 80 messages/hour of 3,700 characters each (3,250 data characters). The time for completion of the total hourly Area A broadcasts then equals $80 \bullet T_{msg}$ = 1,032 seconds or 17.2 minutes. The time for completion of the hourly scheduled SA broadcast is computed similarly to be 4.95 min/hr.

4.3.2.3 Request/Reply and NADIN I Traffic — Line 3

The performance to be obtained by using a 19.2 Kb/s line exclusively for Request/Reply and NADIN I traffic from the WMSC to each NADIN switch is examined in this section. To minimize software requirements at the WMSC, it is assumed that all traffic outbound from the WMSC over this channel is queued up in a single first-come, first-served queue. This traffic includes replies for low- and medium-speed Service A terminals (R/R and SAS) as well as NADIN Type II and Type III messages. It should be noted here that all WMSC generated weather messages are to be of NADIN Priority 4 (revised Appendices G, H, & U, NADIN Specifications).

To model the delays it is assumed that the line acts as an M/M/1 queue, i.e., Poisson arrival process and exponentially distributed service times. Such a model gives reasonably accurate results on the conservative side and so is appropriate in a design effort of this type. It is found in Appendix H that this model reveals average Reply delays of .37 seconds for both low- and medium-speed addresses and 90th percentile delays of 1 second during peak hour.

4.3.3 Concentrator to Switch Analysis

The procedure described in Section 4.2 for message flow from switch to concentrator is inverted to obtain flow procedure from concentrator to switch. That is, there are

multiple queues at the concentrator: one for each Service A circuit. Frames from the queues are served sequentially by the concentrator and sent to the switch. The queue space in each individual queue at the concentrator is assumed limited to space for only 2 frames; but, because of the small traffic load (approximately 4 percent of the switch-to-concentrator traffic) and the fast mean service rate compared with arrival rates, this buffer capacity limitation can be disregarded in the delay analysis.

The average delay is found to be .09 seconds for requests, .12 seconds for collections, and .27 seconds for Level I, Type II messages. The delays are obtained by treating all of the queues at the concentrator as one large queue with Poisson arrivals, whose mean equals the sum of the individual arrival means. Based on the traffic figures in Table 4-9, this gives an arrival rate λ = .308 msg./sec. The service rate is simply the time T_{fr} to send an average single frame message of 1,150 characters. The value of T_{fr} is found as in Section 4.3.2, except that Level 1 traffic has been included in the arrival rate.

$$T_{fr} = .25 \text{ sec./fr.}$$

The value of μ, the mean service rate, is given by

$$\mu = (T_{fr})^{-1} = 4 \text{ fr./sec.}$$

The mean waiting time in the queue is given as usual by:

$$W_q = \frac{\rho}{\mu(1-\rho)} = .02 \text{ sec.}$$

where

$$\rho = \frac{\lambda}{\mu} = .077$$

The 90^{th} percentile wait in the queue is zero. Collection times and request delays are listed in Table 4-9 for convenient reference.

4.3.4 Switch to WMSC Analysis

The link protocol and line capacities have been discussed in Section 4.3.2. On all three lines queueing analysis shows queue wait of less than .01 seconds, so these will not be included in performance results. These performance values are summarized in Table 4.9.

4.3.4.1 Line 1 — SAS Collection

Collection of all data acquired in the A1, A2, and A3 hourly scans by the concentrator requires 1.2 minutes/hour. The average delay for a weather observation message is less than .1 seconds. This is based on hourly throughput of 1,332 Kb/hr. for the larger NADIN switch. The average collection message is 48 characters—an hourly figure of 2,281 messages per switch.

4.3.4.2 Line 2 — Area A and Z Node Collection

Total hourly collection requires 1.3 minutes. The average delay for a message is .24 seconds. These values are based on hourly throughput of 187 Kb/hr. for the larger switch. The average message length is 48 characters/message—an hourly total of 321 msg./hr.

4.3.4.3 Line 3 — Requests and Type II NADIN I Messages

The average delay for a 30-character request is less than .1 seconds as is the average delay for a Type II message. Throughput per hour is 1800 Kb/hr., consisting of 3020 requests of 30 characters average length and 1116 Type II messages of 120 characters average length. There are no Type III messages from a NADIN switch to the WMSC.

4.3.5 Delays for NADIN I Traffic: Switch-to-Switch

The NADIN switches are connected by a 9.6 Kb/s full-duplex link using the ADCCP protocol. The overhead rate is assumed to be 1.2 (cf. NAC Working Memorandum WM-03D.06). All messages are of NADIN Type II with an average length of 120 characters. From Appendix I, the average delay encountered by such a message from switch to switch is approximately .2 sec., of which about .03 seconds represents queueing delay.

These delays are not affected by Service A integration into NADIN because there would normally be no Service A traffic on the switch-to-switch links. However, the NADIN I switch-to-switch delays are needed to determine end-to-end delays for NADIN I traffic, for example from a concentrator associated with the East switch to a concentrator associated with the West switch. Such traffic would be competing with Service A traffic on the switch-to-concentrator links.

4.3.6 NADIN Priority 1 Delays

This short message high priority traffic usually would be exchanged on a single link between intelligent nodes. Delays are given below for the three types of links examined in this memorandum: WMSC—switch, switch—concentrator, and switch—switch.

4.3.6.1 WMSC—Switch

It is not clear that any message from the WMSC to a NADIN switch could be Priority 1, but if one occurred it would be sent on Line 3, the 19.2 Kb/s line to be used for Request/Reply and NADIN I traffic. From Appendix J, the average delay expected is .23 sec. for an average length Priority 1 message.

Switch—Concentrator

Most Priority 1 messages on this link are assumed to be addressed to the switch or concentrator themselves rather than for relay to some other destination. In this case, because of the very low frequency with which these messages occur, there would be essentially no queueing delay. Therefore, the entire delay is the transmission time which is [illegible] seconds.

Occasionally a Priority 1 message may be sent by the switch to the concentrator for forwarding, e.g., to an Area B circuit. However, the expected delay due to the switch's being [illegible] Type II message to Area B at the instant the Priority 1 message [illegible] service at the switch is less than 1 millisecond and can be safely neglected.

4.3.6.3 Switch—Switch

As noted in Section 4.5, the average delay for all NADIN I short message traffic from switch-to-switch is approximately .2 seconds including Priority 1 messages in particular.

4.3.7 Analysis of Buffer Capacity

The buffer capacity required at the switch to handle traffic during a period when there is no broadcast to SAS circuits is determined in this section. Buffer space is estimated for Service A stochastic traffic from WMSC to switch (Reply). A determination is also made of buffer capacity required during the longest SAS broadcast period if no flow control exists.

To determine the buffer space required for reply traffic from the WMSC to a switch the method of Chernoff bounds is used (see Wozencraft and Jacobs, p.97). The details are presented in Appendix K. This estimation procedure is useful when the tail of the sum of multiple distributions which are identical (namely the waiting time distribution associated with replies queued at the switch for forwarding to its 12 concentrators) are to be determined.

The waiting time distribution for the combined medium- and low-speed traffic is the

p.d.f. of $w = W_1' + W_2'$

where

W_1' = queueing delay for medium speed replies (one concentrator)

W_2' = queueing delay for low speed replies (one concentrator).

The p.d.f. for $(W_1' + W_2')$ is denoted by f_w and is given by the formula

$$f_w = \delta(t) + (C_1 e^{-At} + C_2 e^{-Dt})U_0(t)$$

where

$\delta(t)$ = unit impulse function at the origin

$$A = 1.6483$$

$$D = 1.6493$$

$$C_1 = 15.25$$

$$C_2 = -14.84$$

$$U_0(t) = \begin{cases} 0, & \text{for } t < 0 \\ 1, & \text{for } t \geq 0 \end{cases}$$

The Chernoff bound then consists of the estimate

$$\text{Prob. of overflow} \leq \left[E\left[\exp(\lambda_0(w-d)) \right] \right]^{12}$$

where

$E[Y]$ = expected value of a random variable Y

$d = \dfrac{B}{12C}$

B = Buffer size in Kbytes

C = line capacity in Kcharacters/sec. (SW-Conc)

and

λ_0 is determined implicitly by the equation

$$\frac{E\left[w \exp(\lambda_0 w)\right]}{E\left[\exp(\lambda_0 w)\right]} = d.$$

This method was used to obtain the value of B which gives 95% probability of non overflow although the method can be used to obtain B for other probabilities.

The additional buffer capacity B which is needed during the largest broadcast is simply given by

$$B_1 = \left[(S'_{in} - S'_{out}) + (S_{in} - S_{out})\right] \bullet T$$

where

T = time of hourly SA broadcast to SAS circuits in sec.

S'_{in} = flow into switch from WMSC for SAS broadcast in Kb/sec

S'_{out} = flow out of switch to 12 concentrators for SAS broadcast in Kb/sec

S_{in} = flow into switch from WMSC for Area A broadcast in Kb/sec

S_{out} = flow out of switch to 12 concentrators for Area A broadcast in Kb/sec

Further details are in Appendix K.

4.3.8 Local Access Analysis

Under the NADIN alternative the local access portion of the Service A network, that is the multipoint lines connecting the remote nodes to the NADIN concentrators, would continue functioning in very much the same manner as the current Service A circuits with the important difference that the WMSC is replaced by the concentrator as the immediate destination and origin for the remote terminals input and output respectively. The major change under the NADIN alternative is the cost effectiveness of circuits with fewer nodes per multidrop line than in the non-NADIN alternative. In this section delays and completion times are obtained as a function of N the number of nodes/ckt for the various classes of terminals, SAS, Area A and Request/Reply. In addition, the performance of Service A in a NADIN-independent mode of operation is presented.

As pointed out in Section 4.1.1, the average number of nodes per circuit in the most cost effective NADIN implementation for SAS circuits is 3 nodes/circuit with an actual maximum of 9. The performance results for several node numbers are summarized below in Table 4-11.

4.3.8.1 SAS Circuits

It is assumed that whenever the ARTCC concentrator is not engaged in disseminating broadcast or in collecting data from SAS circuits, then it will poll SAS nodes continuously for possible inputs or requests. This provides a total of just over 50 minutes for a 10-node SAS circuit during which requests can be entered. The average delays shown in Table 4-11 for Request/Reply are computed, assuming that all requests arrive at a controller during the 50 min./hr. period. As currently structured, the WMSC procedure does not permit a request to be entered during the entire SA broadcast or FT or other priority broadcasts. Thus a request appearing at a controller at H+03 must wait until nearly H+06 to be entered to the WMSC. This situation will not be appreciably improved by NADIN except in that the average SA broadcast time would be reduced on the average 3-node SAS circuit, thus reducing the line's non-availability for Request/Reply traffic.

Performance models based on the ANSI X3.28-2.7 protocol are constructed in Appendix L and used to obtain the broadcast and collection performance shown in Table 4-11 in terms of completion times and effective circuit capacity for broadcast. A queueing model is constructed in Appendix L and used to determine the delays for SAS requests and for replies shown in Table 4-11. These delays are shown to be functions of N, the number of nodes per SAS multipoint line.

4.3.8.2 Area A Local Performance

Area A performance would not be significantly affected by NADIN integration. Broadcast completion times would be essentialy unchanged although collection of weather data would be improved by NADIN because the centralized nature of the network makes it cost effective to have multipoint lines with fewer nodes. Thus, for example, the SA poll (AI Scan) can be completed in an average of 75.5 seconds for a typical Area A circuit in the NADIN alternative.

The performance results shown below are for the local access average size Area A circuit up to the NADIN concentrator.

Total Broadcast Minutes/hr.	39.6
SA Broadcast Minutes/hr.	11
Total Scheduled Broadcast Minutes/hr.	24.6
Total Unscheduled Broadcast Minutes/hr.	13.8
Urgent Broadcast Minutes/hr.	1.2
Total Collection Minutes/hr.	2.1
SA Collection Minutes/hr.	1.26

Broadcast is assumed to be distributed at .97 information rate. This is based on examination of typical SA broadcasts. Total broadcast time per hour is then

$$T_{BR} = \frac{C_D \bullet 7.5}{24 \bullet 75 \bullet 60 \bullet .97}$$

where

C_D = daily characters of broadcast on busy day/circuit = 554,000

T_{BR} = time in minutes per hour of broadcast = 39.6 min.

Collection will be carried out by the concentrator which will poll each node using essentially the protocol now used by the WMSC in polling Area A terminals. The essential features are that the poll contains 10 characters and negative response by a terminal is indicated by 5 seconds of no response. If the station polled has a response, it sends — TEXT + 8 characters — or if collection is unscheduled, it prefixes transmission with time date group characters. This leads to an informate rate of .50 for scheduled collection. This calculation requires several other protocol parameters. At the apparent conclusion of the report, the concentrator will wait .3 seconds before polling next station. Further, since a polled station has 5 seconds to respond to a poll before being considered a negative response, it is assumed that the average response time to a poll is 2.5 seconds. Actual response is probably faster but this is conservative. Adding local line propagation of .04 seconds gives a total of 9.44 seconds for a poll followed by transmission of a report.

Collection of 8 SA's therefore requires 75.5 seconds and collection of all inputs requires 124 seconds.

4.3.8.3 Local Request/Reply Circuit Performance

Under the NADIN alternative for Service A Request/Reply nodes will be polled by the NADIN concentrator for possible input of requests. When a request is inputted to the concentrator, the concentrator will immediately forward it to the WMSC for processing. However, the concentrator will also resume polling as soon as it has received the end of the request from the R/R terminal.

There are two queues, one at the terminal for requests and one at the concentrator for replies. These are modeled in Appendix M as M/M/1 queues and the delays are shown in Table 4-12 for various values of N, the number of nodes per circuit.

NADIN permits the cost effective use of Request/Reply circuits with fewer nodes (average 3 nodes/ckt) than the non-NADIN alternative (average 4.5 nodes/ckt), which results in significantly shorter delays (by 49%) in the NADIN alternative. However, delays are still quite long because of the polling procedure which uses a 5 second time-out and leads to significant polling delays even for a line with only 3 nodes/ckt.

4.3.9 Non-NADIN Service A Performance

The modeling used to determine the performance of the local Service A circuits in the NADIN alternative can be used to obtain the delays and completion times for Service A operation independent of NADIN. The only major difference is that for each class of terminals, Area A, Request/Reply and SAS, the average circuit has more nodes in the non-NADIN design than with NADIN. The performance parameters are listed in Tables 4-8 and 4-9.

4.4 TRAFFIC REQUIREMENTS

Service A traffic must be interpreted in a form which facilitates evaluation of its impact on NADIN and the performance levels which NADIN will provide. Based on the detailed traffic description in Appendix N traffic flow is analyzed on the local access level, the NADIN switch-concentrator links and on the WMSC-NADIN switch links. NADIN I traffic on switch-switch links is discussed. Finally, delay requirements are given.

4.4.1 Traffic on the Local Access Circuits

4.4.1.1 Broadcast and Collection

Broadcast to SAS circuits is determined for peak hour using the profile of the WMSC data base reflected in the AWP to FSDPS traffic reports contained in Tables 4-13, 4-14 and 4-15, with the exception that message lengths are reduced by one-half to reflect actual message lengths. The peak hour for scheduled broadcasts refers to an hour in which FT reports are transmitted in addition to the hourly SA and SD reports. Unscheduled broadcast received by SAS circuits are shown in Table 4-14 with the message length correction. These values are shown in Table 4-16. Also shown in Table 4-16 is the hourly Surface Observation (SA) broadcast to medium speed circuits.

SAS Collection is estimated as a percentage of broadcast received.

Discussions with the WMSC system analyst and the Western Union SAS project manager indicate that input (exclusive of R/R) is about five percent of broadcast per circuit. An examination of the daily report shows this to be a conservative estimate as the highest ratio that could be found was 4.7 percent. This ratio is not likely to be affected by weather conditions and to be conservative will be chosen to be 8 percent. The results are shown in Table 4-16.

It is assumed that all Area A circuits and ARTCC terminal nodes in the same ARTCC region will receive the same broadcasts from WMSC. Further, it is assumed that the average daily broadcast will remain the same as that currently received by Area A circuits. This figure is 450,000 characters per day based on the WMSC daily traffic report. Multiplying by the busy day factor, 1.23 from Appendix O gives the value for total hourly broadcast in Table 4-16. The breakdown into Scheduled, Unscheduled, and Urgent Broadcast is obtained by assuming the same percentage decomposition of Broadcasts as for SAS circuits.

The values in Table 4-16 follow from the assignment of 1500 characters per day for a typical Area A node based on the WMSC daily report. This number is multiplied by the busy day factor 1.23 and by 8, the maximum number of nodes per reconfigured Area A circuit to obtain the collection characters/busy day/circuit shown in Table 4-16. The division into scheduled, unscheduled, and urgent follows the same percentages used for broadcast.

ARTCC Broadcast figures in Table 4-16 are based on the conservative assumption that each ARTCC Service A terminal node will receive the same broadcasts as the Area A circuits in the ARTCC region. Currently, these nodes receive an average of approximately 60 percent of an Area A circuit broadcast. Based on the WMSC daily traffic summary and scaling for peak hour and peak day, the collection traffic input by the average ARTCC terminal node is 8.3 Kb/hr.

4.4.1.2 Request/Reply Traffic

The concept of a peak hour for Request/Reply is used to determine the peak throughput for R/R traffic. It has been determined based on discussions with an FSS specialist that there are 3 peak hours in the morning and 2 peak hours in the afternoon during which traffic volume is approximately four times normal.

From Appendix P, the peak hour Requests each eliciting a reply originate at SAS controllers at the average rate of 35.4 requests/SAS node/peak hour. Requests from low speed Request/Reply nodes are determined to be generated at the average rate of 3.07 requests/R/R Node/peak hour. This traffic must be expressed on a per node basis for performance evaluation of various multipoint designs. Message lengths are listed in Table 4-17 together with other traffic measures.

It is assumed that Request/Reply traffic generated by ARTCC terminal nodes will be twice that of a half-duplex Request/Reply terminal. This is based on the WMSC daily circuit report and is conservative.

4.4.2 Traffic on NADIN Switch to Concentrator Links

Traffic is determined for an average Concentrator which is defined (based on the design findings) as one serving an ARTCC with 3 SAS circuits, 3 Area A circuits, 3 Request/Reply circuits and one ARTCC terminal node. This traffic is calculated from the traffic described above in Section 4.4.1 on the local access portion of the network. In addition, the NADIN I base traffic is examined on this link.

Service A Broadcast addressed to SAS or Area A circuits is obtained by multiplying the per circuit broadcast by three since the concentrator wil receive an individual copy of the broadcast from the switch for each appropriate circuit. These values are shown in Table 2-4. SAS and Area A collection traffic is obtained in the same manner.

SAS Request/Reply traffic can be computed by multiplying the number of requests per SAS Node by the average number of SAS nodes per ARTCC. Low speed request/reply traffic on the switch-concentrator link is found in the same manner. These values are shown in Table 2-4.

Service A traffic would be in addition to the NADIN I base traffic (on the switch-concentrator link) which is summarized in Table 2-4. This is primarily short message traffic whose individual sources and sinks are listed in Appendix Q based on Appendix Z of the NADIN Specifications.

4.4.3 WMSC-NADIN Switch Traffic

The Service A and NADIN I traffic on the WMSC-Switch link is shown in Table 2-4. Request/Reply traffic as well as Collection Traffic is obtained by multiplying switch-concentrator traffic by 12, the number of concentrators associated with the large NADIN switch. Broadcast traffic however, is derived in a slightly different manner because the WMSC is assumed to send to an ARTCC only one SAS broadcast, for example, which the switch duplicates and forwards to the SAS local circuits. Therefore, the broadcast throughput to a single average SAS or Area A circuit is multiplied by 12 to obtain the WMSC-Switch broadcast throughput, shown in Table 2-4. A very small volume of NADIN I traffic (taken from Appendix Z of the NADIN Specifications) will also be carried on the WMSC-Switch links, most of which is short message traffic. This is included in Table 2-4.

4.4.4 Switch-Switch Traffic

It is also necessary to consider the NADIN I traffic on the switch-to-switch link to determine delays on this link for NADIN I traffic to be used in end-to-end delay analysis. This traffic is shown in Appendix R. There will normally be no Service A traffic between the NADIN switches.

4.4.5 Delay Requirements

The network will consist of NADIN starting at the concentrator, through the switch, and ending at the message level of WMSC. This is reflected on Figure 3-3 as A through D and E through H.

Network delay requirements for Requests, Replies, NADIN I traffic and priority collection or dissemination are taken to be an average one way end-to-end delay of 2 seconds with a 90th percentile delay of less than 4 seconds.

On the local design although delay requirements are not specified the aim is to obtain delays with the NADIN design which are sufficiently shorter than the non-NADIN approach that the total end-to-end delays using NADIN between remote DTE and WMSC will be less than those obtained in the non-NADIN approach to Service A.

NADIN I priority messages are required to satisfy a NADIN end-to-end delay requirement of 1.5 seconds.

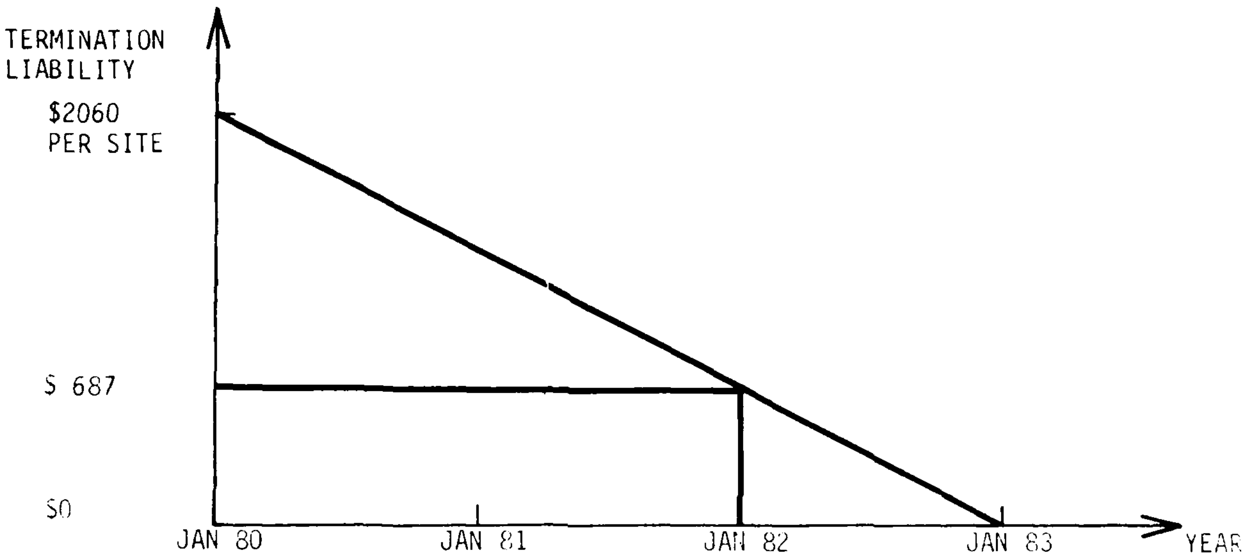


FIGURE 4-1: SAS TERMINATION LIABILITY

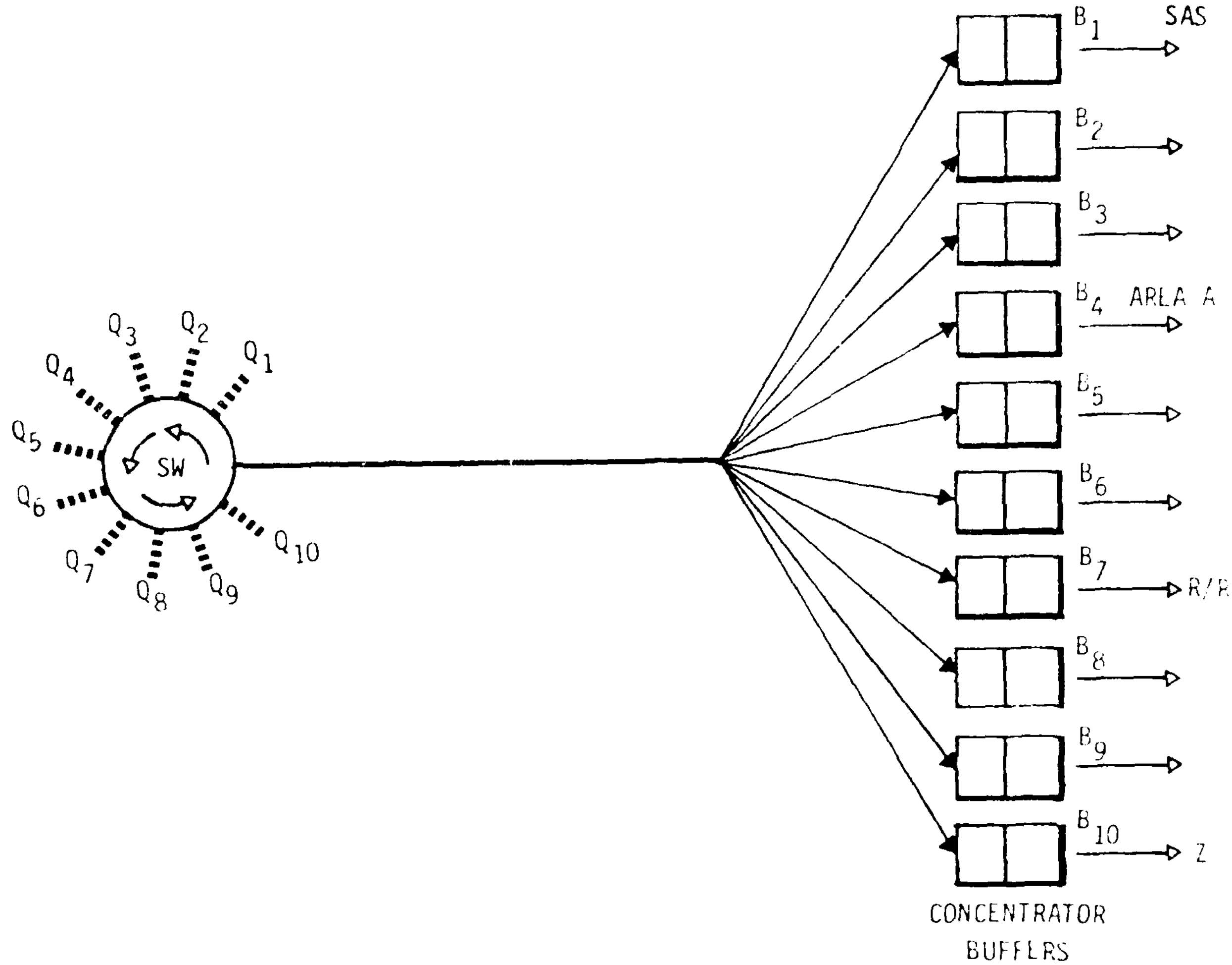


FIGURE 4-2: SWITCH TO CONCENTRATOR MODEL

TYPE	NODES PER CIRCUIT: CONSTRAINT NODES	ACTUAL MAX. NODES	MEAN NO. OF NODES/CKT.
SAS	10	9	3
AREA A	8	8	5
R/R	4	4	3
ARTCC	1	1	1

	CIRCUIT TOTALS: TOTAL NO. OF CKTS.	AVG. CKT/ CENTER	MAX. CKT/ CENTER
SAS	51	3	5
AREA A	50	3	4
R/R	66	3	5
ARTCC	19	1	1

TABLE 4-1: NADIN LOCAL ACCESS DESIGN RESULTS

AD-A100 009 NETWORK ANALYSIS CORP VIENNA VA F/G 17/2
COMMUNICATIONS SUPPORT FOR AREA A AND REQUEST/REPLY.(U)
APR 81 DOT-FA79WA-4335
UNCLASSIFIED NAC/FR.303C FAA-RD-81-37 NL

2 OF 3
AD
A100009

ARTCC	SAS Ckts.	Area A Ckts.	R/R Ckts.	ARTCC Serv. A	Total
ZAB	4	2	4	1	11
ZAU	1	2	2	1	6
ZBW	2	3	3	1	9
ZDC	3	2	3	1	9
ZDV	3	2	4	1	10
ZFW	3	2	4	1	10
ZHU	5	3	3	1	12
ZID	1	3	3	1	8
ZJX	2	2	3	1	8
ZKC	2	2	3	-	7
ZLA	2	4	4	1	11
ZLC	3	3	4	1	11
ZMA	4	3	3	1	11
ZME	3	3	3	1	10
ZMP	3	3	5	1	12
ZNY	2	3	3	1	9
ZOA	1	2	3	1	7
ZOB	3	3	3	1	10
ZSE	2	2	3	1	8
ZTL	2	1	3	1	7

TABLE 4-2 NUMBER OF CIRCUITS BY CENTER

	MRC	ONE TIME COSTS		
		HARDWARE	SOFTWARE	TOTAL
LOCAL ACCESS	$75,246	$231,248	$240,000	$471,248
SWITCH-CONCENTRATOR	$ 44	$ 52,137	$150,000	$202,137
ALTERNATIVE 2.1 WMSC-SWITCH	$ 5,590	$197,085	——	$197,085
TOTAL	$80,880	$480,470	$390,000	$870,470
ALTERNATIVE 2.2 WMSC-SWITCH	$ 9,260	$ 22,725	——	$ 22,723
TOTAL	$84,550	$306,110	$390,000	$696,110

TABLE 4-3: NADIN TOTAL COSTS

LOCAL ACCESS:	COST/MILE	MILES	MILEAGE COST	DROP COST	TOTAL
SAS	$.56	22,046	$12,346	$ 8,400	$20,746
AREA A	$.28	10,880	$ 6,093	$13,077	$19,170
REQUEST/REPLY	$.28	10,920	$ 6,115	$10,089	$16,204
Z (ARTCC)	—	—	—	$ 1,645	$ 1,645
SUBTOTAL		43,846	$24,554	$33,211	$57,765
IXCM	$1.25	3,920	$ 4,900		$ 4,900
SUBTOTAL OF MRC					$62,665
TELPAK SERVICE FEE .015 of MRC					$ 940
SAS MODEM LEASING/MONTH $60/UNIT					$11,640
TOTAL LOCAL ACCESS/MONTH					$75,245
SWITCH TO CONCENTRATOR:					
D1 CONDITIONING	$14.65/LINE	3 LINES			$ 44
TOTAL					$75,289

TABLE 4-4: SERVICE A NADIN MONTHLY RECURRING COSTS EXCLUSIVE OF WMSC-SWITCH

COST COMPONENTS	UNIT COST	QUANTITY	COST
HARDWARE:			
9600 B/S MODEMS (SWITCH-CONCENTRATOR)	$8,500	6	$ 51,000
PORTS (CONCENTRATOR)	$ 500	189	$ 94,500
INSTALLATION CHARGES (REMOTE DTE)	$54.15	635	$ 34,385
TERMINATION LIABILITY *(SAS)	$ 687	149	$102,363
D1 CONDITIONING INSTALLATION	$ 163	3	$ 489
MODEM (9600 B/S) INSTALLATION CHARGE	$ 216	3	$ 648
SUBTOTAL			$283,385
SOFTWARE: $100/INSTRUCTION			
CONCENTRATOR POLLING & PROTOCOL		2400=4(600)	$240,000
SWITCH ROUTING EXPANSION		500	50,000
SWITCH BROADCAST DUPLICATION		2(500)	$100,000
SUBTOTAL			$390,000
TOTAL			$673,385

* LEVIED BY WESTERN UNION
ASSUMING RECONFIGURATION
ON JANUARY 1, 1982.

TABLE 4-5: NADIN ONE TIME COSTS EXCLUDING WMSC LINKS

ONE TIME COSTS:

ALTERNATIVE 2.1

ITEM	UNIT PRICE	QUANTITY	COST
MODEM PURCHASE (9600 B/S)	$8,500	16	$136,000
MODEM PURCHASE (2400 B/S)	$2,500	4	$ 10,000
DIPLEXOR PURCHASE	$5,000	8	$ 40,000
D1 CONDITIONING INSTALLATION (9600 B/S LINES)	$ 163	8	$ 1,304
MODEM INSTALLATION (9600 B/S)	$ 216	16	$ 3,456
MODEM INSTALLATION (2400 B/S)	$81.20	4	$ 325
PORTS	$ 500	12	$ 6,000
SUBTOTAL			$197,085

ALTERNATIVE 2.2

ITEM	UNIT PRICE	QUANTITY	COST
PORTS	$ 500	12	$ 6,000
MULTIPLEXOR PURCHASE	$4,000	4	$ 16,000
DDS INSTALLATION CHARGE (INCLUDES DSU INSTALLATION)	$180.75	4	$ 723
SUBTOTAL			$ 22,723

RECURRING MONTHLY COSTS:

ALTERNATIVE 2.1

ITEM	UNIT PRICE	QUANTITY	COST
MILEAGE	$.56	8075 MILES	$ 4,522
DROPS	$43.30	20	$ 866
D1 CONDITIONING	$14.65	8	$ 117
SUBTOTAL			$ 5,505
TELPAK SERVICE CHARGE	$.015/DOLLAR OF MRC		$ 83
TOTAL			$ 5,588

ALTERNATIVE 2.2

ITEM	UNIT PRICE	QUANTITY	COST
MILEAGE	DDS RATES	915+700	$ 6,662
DROPS (INCLUDES DSU LEASE)	$650	4	$ 2,600
SUBTOTAL			$ 9,262

TABLE 4-6: WMSC-SW COSTS

	COST/MILE	MILES	MILEAGE COST	DROP COST	TOTAL
SAS	.56	29,627	$16,590	$ 6,970	$23,560
AREA A	.28	47,789	$13,380	$12,945	$26,325
R/R	.28	45,021	$12,606	$ 9,180	$21,786
Z (ARTCC)	.28	16,050	$ 4,494	$ 1,645	$ 6,139
SUBTOTAL			$47,070	$30,740	$77,815
IXC	1.25/MI	3920	$ 4,900		$ 4,900
SUBTOTAL					$82,715
TELPAK SERVICE CHARGE	.015 OF MRC (LINES & DROPS ONLY)				$1,240
SUBTOTAL					$83,956
SAS MODEM LEASING	$60/MODEM	161 MODEMS			$9,660
TOTAL					$93,60

TABLE 4-7: NON-NADIN SERVICE A COSTS (ALL MONTHLY RECURRING)

OUTBOUND

	NADIN				
	WMSC TO SWITCH	SWITCH TO CONCEN-TRATOR	CONCEN-TRATOR TO REMOTE NODE	TOTAL DELAY	NON-NADIN DELAY
AVG. SAS REPLY	.37	.66	.59	1.62	1.57
90th PERCENTILE SAS REPLY	1.00	.99	.46	2.45	4.46
AVG. LOW SPEED REPLY	.37	1.4	13.00	14.77	24.8
90th PERCENTILE LOW SPEED REPLY	1.00	1.3	46	48.3	74.7

INBOUND

	NADIN				
	REMOTE NODE TO CONCEN-TRATOR	CONCEN-TRATOR TO SWITCH	SWITCH TO WMSC	TOTAL DELAY	NON-NADIN DELAY
AVG. SAS REQUEST	1.14	.1	.1	1.34	3.73
90th PERCENTILE SAS REQUEST	1.73	.1	.1	1.93	9.29
LOW. SPEED REQUEST	23.6	.1	.1	23.8	56
90th PERCENTILE LOW SPEED REQUEST	68.84	.1	.1	69.04	116.28

TABLE 4-8: NADIN VS NON-NADIN REQUEST/REPLY DELAYS (SECONDS)

MINUTES/HR CIRCUIT ENGAGED IN ACTIVITY

SAS

	NADIN				NON-NADIN
	WMSC-SW	SW-CONC (WORST CASE)	LOCAL (AVG CKT)	NADIN NET COMPLETION TIME	AVG CKT
TOTAL BROADCAST	7.25	8.66	7.01	8.66	8.3
SA BROADCAST	2.1	2.46	2	2.46	2.35
TOTAL COLLECTION	1.2	1.3	.21	1.3	.58
SA COLLECTION	.82	.89	.15	.89	.4

AREA A

TOTAL BROADCAST	17.2	42.3	39.6	42.3	39.6
SA BROADCAST	4.95	11.7	11	11.7	11
TOTAL COLLECTION	1.3	.1	2.1	2.1	2.1
SA COLLECTION	.78	.06	1.26	1.26	1.26

TABLE 4-9 BROADCAST & COLLECTION OF WEATHER DATA

	WMSC TO LARGER SWITCH			LARGER SWITCH TO AVG CONCENTRATOR	
MESSAGE TYPE	AVG CHAR/MSG	MSG/HR	Kb/HR	MSG/HR	Kb/HR
NADIN I-TYPE II	120	756	726	1,116	1,070
NADIN I-TYPE III	3,000	14	336	48	1,150
SAS BROADCAST	3,700	59	1,740	268	6,960
AREA A BROADCAST	3,700	18	518	80	2,071
SAS REPLY	690	229	1,260	2,740	15,120
LOW SPEED REPLY	690	23	128	278	1,537

TABLE 4-10 TRAFFIC SUMMARY - OUTBOUND

NODES PER CIRCUIT	10	6	3
TOTAL BROADCAST MIN./HR.	8.76	7.75	7.01
SA BROADCAST MIN./HR.	2.49	2.2	2
SCHED. BROADCAST MIN./HR.	5.36	4.74	4.29
UNSCHED. BROADCAST MIN./HR.	3.3	2.92	2.64
URGENT BROADCAST MIN./HR.	.1	.088	.08
TOTAL COLLECTION MIN./HR.	.73	.42	.21
SA COLLECTION MIN./HR.	.5	.30	.15
AVG. REPLY DELAY (SEC)	1.93	1.06	.59
90^{th} PERCENTILE REPLY DELAY (SEC)	6.23	3.16	.46
AVG. REQUEST DELAY (SEC)	5.86	2.46	1.14
90^{th} PERCENTILE REQUEST DELAY (SEC)	15.80	6.59	1.73

TABLE 4-11 LOCAL ACCESS SAS PERFORMANCE VS NUMBER OF NODES/CKT.

DELAYS (SECONDS)

NUMBER OF NODES PER CKT.	2	3	4	6	8
AVG. REQUEST DELAY	19.1	23.6	45.2	91.9	192
AVG. REPLY DELAY	9.2	13.1	20.8	37.3	60.6
AVG. REQUEST QUEUE WAIT	11.5	20	31.6	72.3	166
AVG. REPLY QUEUE WAIT	9.1	13	20.7	37.2	60.5
90th PERCENTILE REQUEST DELAY	35.4	79.7	129.9	241	488
90th PERCENTILE REPLY DELAY	15.9	46	74.7	132	200

TABLE 4-12 LOCAL DELAYS FOR LOW SPEED REQUEST/REPLY

ABBREVIATION	MESSAGE TYPE	MESSAGE LENGTH DISTRIBUTION	MEAN LENGTH (K BITS)	STANDARD DEVIATION BIAS (K BITS)	NUMBER OF REPORTS PER TRANSMISSION	TIME OF TRANSMISSION	FREQUENCY OF TRANSMISSION
1. SA	SURFACE OBSERVATION	NORMAL	0.72	0.128	1374	H+00	1/HR*
2. SA	MILITARY SURFACE OBSERVATION	NORMAL	0.72	0.128	108	H+25	1/HR
3. FT	TERMINAL FORECAST	NORMAL	1.224	0.24	[illegible]	H+40	1/8HR
4. FG	WINDS ALOFT	FIXED	760	--	1	H+00	1/12HR
5. FA	AREA FORECAST	NORMAL	19.2	2.4	11	H+40	1/12HR
6. FX	PROGNOSTIC MAP DISCUSSION	NORMAL	[illegible]	4	1		[illegible]/DAY
7. TWEB**	ROUTE FORECAST	NORMAL	2.56	[illegible]	[illegible]	H+15 (MORNING, EVENING)	6/DAY
8. TWEB**	SYNOPSIS	NORMAL	3.12	0.96	23	H+36	6/DAY
9. SD	RADAR WEATHER REPORTS	NORMAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*SAME MESSAGE TYPE IN FSDPS TO AWP TRAFFIC
**NOT INCLUDED IN WMSC BROADCASTS

TABLE 4-13: SCHEDULED MESSAGES FROM AWP TO FSDPS

ABBREVIATION	MESSAGE TYPE	MESSAGE LENGTH DISTRIBUTION	MEAN (KBITS)	STANDARD DEVIATION OR BIAS (KBITS)	INTERARRIVAL TIME DISTRIBUTION	AVERAGE NUMBER OF MESSAGES/PEAK HOUR
1. DNO	DOMESTIC NOTAMS	BIASED EXP.	0.4		EXPONENTIAL	78*
2. INO	INTERNATIONAL NOTAMS	BIASED EXP.	1.88		EXPONENTIAL	32
3. NNO	CARF, NFDC NOTAMS	BIASED EXP.	1.8		EXPONENTIAL	2
4. CNO	NOTAMS CANCELLATION	BIASED EXP.	0.2		EXPONENTIAL	112*
5. UA	PILOT REPORTS	NORMAL	1.44	0.24	EXPONENTIAL	430*
6. WH	HURRICANE ADVISORY	NORMAL	6.4	0.8	EXPONENTIAL	3
7. WW	WEATHER WARNINGS	NORMAL	5.6	1.2	EXPONENTIAL	2
8. WO	TROPICAL DEPRESSION ADVISORY	NORMAL	6.4	1.6	EXPONENTIAL	3
9. AC	SEVERE WEATHER NARRATIVE	NORMAL	12	3.2	EXPONENTIAL	1
10. WA	AIRMET	NORMAL	1.95	0.24	EXPONENTIAL	5
11. WS	SIGMET	NORMAL	1.73	0.24	EXPONENTIAL	5
12. SP	SPECIAL OBSERVATION	NORMAL	0.72	0.13	EXPONENTIAL	165*
13. SW	SUPPLEMENTARY OBSERVATION	NORMAL	0.72	0.13	EXPONENTIAL	[illegible]*
14. FX	PROGNOSTIC MAP DIVISION	NORMAL	16	4	EXPONENTIAL	[illegible]
15.	AMENDMENTS	BIASED EXP.	2.69		EXPONENTIAL	[illegible]
16.	MISCELLANEOUS	NORMAL	0.4	0.12	EXPONENTIAL	[illegible]
17.**	ATSCC MESSAGES	NORMAL	2	0.4	EXPONENTIAL	5
18.**	MILITARY OPERATIONS	NORMAL	0.48	[illegible]	EXPONENTIAL	65
19.**	AFOS GRAPHICS	NORMAL	4	1	EXPONENTIAL	[illegible]

*SAME MESSAGE TYPE IN FSDPS TO AWP TRAFFIC
**NOT INCLUDED IN WMSC BROADCASTS

TABLE 4-14: UNSCHEDULED MESSAGES FROM AWP TO FSDPS

ABBREVIATION	MESSAGE TYPE	MESSAGE LENGTH DISTRIBUTION	MEAN (KBITS)	STANDARD DEVIATION OR BIAS (KBITS)	INTERARRIVAL TIME DISTRIBUTION	AVERAGE NUMBER OF MESSAGES/PEAK HOUR
1. USP	URGENT SPECIAL SPECIAL OBSERVATION	NORMAL	0.72	0.13	EXPONENTIAL	5*
2. UUA	URGENT SPECIAL PILOT REPORT	NORMAL	1.44	0.24	EXPONENTIAL	5*

* SAME MESSAGE TYPE IN FSDPS TO AWP TRAFFIC

TABLE 4-15: URGENT MESSAGES FROM AWP TO FSDPS

TYPE	SAS CKT WITH 10* NODES	AREA A CKT WITH 8* NODES	ARTCC TERMINAL
SCHEDULED BROADCAST	355	103	103
UNSCHEDULED BROADCAST	220	63.7	63.7
UNSCHEDULED BROADCAST	4.1	5.4	5.4
TOTAL BROADCAST	580	173	173
SA BROADCAST	-	-	-
SCHEDULED COLLECTION	28.2	2.8	-
UNSCHEDULED COLLECTION	17.6	1.7	-
URGENT COLLECTION	.4	.2	-
TOTAL COLLECTION	46.2	4.7	8.4

*MAXIMUM NUMBER OF NODES/CKT IN LOCAL ACCESS DESIGN

TABLE 4-16 LOCAL BROADCAST & COLLECTION - Kb/PEAK HOUR

	REQUEST		
	MSG/NODE/HR	MSG/NODE/SEC	AVG. CHAR/MSG
SAS	35.4	.0118*	30
REQUEST/REPLY	3	.00083	30
ARTCC TERMINAL	6	.00167	30

*BASED ON 50 MINUTES AVAILABLE PER HOUR.

	REPLY		
	MSG/NODE/HR	MSG/NODE/SEC	AVG. CHAR/MSG
SAS	35.4	.0098*	690
REQUEST/REPLY	3	.00083	690
ARTCC TERMINAL	6	.00167	690

*BASED ON 50 MINUTES AVAILABLE PER HOUR

TABLE 4-17 PER NODE REQUEST REPLY TRAFFIC

APPENDIX A

DESCRIPTION OF CURRENT SERVICE A NODE TYPES AND THEIR APPLICATIONS

A.1 NODAL IDENTIFICATION AND APPLICATION

The current Service A nodes are described below in terms of application and physical type.

A.1.1 Terminals

The low speed terminals are almost exclusively electromechanical teletype Model 28's and are used for both Area A and Request/Reply applications. The Area A terminal is used to transmit Surface Observations (SA), Pilot Reports (PIREP), and Notices to Airmen (NOTAMS) to the WMSC while the receive capability is used to acquire broadcasts from the WMSC. The Request/Reply terminal is used on an interactive basis to obtain information during a pilot brief given by a flight specialist at an FSS. The requested weather products are those which are not routinely received as part of the Area A broadcast for that particular station. Some facilities that have an Area A terminal do not transmit Surface Observations and as a consequence have receive-only (RO) terminals. The receipt medium for broadcasts on Area A is paper while the transmit medium is paper tape.

A.1.2 Cluster Terminals

The cluster terminal controllers are an integral component of the Leased Service A provided by Western Union. The controller itself is a GS-200 and its functional classification is a data concentrator. The application of the Leased Service A is the provision of a service that combines the Area A and Request/Reply at Flight Service Stations. Unlike the facility that has low speed terminals and paper storage of Area A broadcasts, the SAS facility stores broadcasts magnetically on floppy disc. This data is available for local query and display on keyboard video display tubes (KVDT). If the requested information is not resident on this local database, a query is forwarded to the WMSC as a Request/Reply message.

A.1.3 Resource Node

The WMSC acts as the nodal point for collection, dissemination, processing, and storage of all information transported for Area A and Request/Reply service. It consists of a Phillips DS-714 computer system that currently services the entire MWTCS. Its hourly throughput exceeds 6,000,000 characters and its capacity is unknown. The WMSC, in conjunction with leased lines, serves not only as a resource node but also as a communication utility providing such functions as line management, polling, (etc.).

A.2 NODAL INTERFACE REQUIREMENTS

Interface requirements identify the physical and operational features that are necessary to facilitate interconnection. Although not used in the alternative analysis, they are necessary as they may impose constraints on compatibility, impact performance factors such as throughput (protocol overhead), and must be known to specify any NADIN specification if integration is chosen. In the requirements analysis, the depth of interface requirements are not that of an Interface Control Document (ICD), but merely that necessary to characterize the interface adequately to identify the constraints for such developments as Technical Data Packages (TDP) at a later date. Since each terminal and controller connects to the WMSC, the WMSC has like interface requirements.

Physical Control

Electrical Interface

TTY 28	:	MILSTD 188C (Current Loop)
Controller	:	RS-232C (Balanced Voltage Driven)

Character Code

TTY28	:	International Telecommunications Code Number Two (ITA-2)
Controller	:	American Standard Code for Information Interchange (ASCII)

Mode

TTY28	:	Area A	-	Half Duplex
		R/R	-	Half Duplex
		Dedicated ARTCC	-	Full Duplex
		Transmission	-	Asynchronous
Controller	:	SAS	-	Full Duplex
		Transmission	-	Synchronous

Speed

TTY28	:	75 bps
Controller	:	2400 bps

Link Control & Message Control

Protocol

TTY28	:	Area A	-	Special (as delineated in FAA directive 7110.10D)
		R/R	-	Special (as delineated in FAA Directive 7110.10D)
		Dedicated ARTCC	-	Special (Undetermined)
Controller	:	SAS	-	ANSI X3.28-1976 Subcategory X2.7 as described in FAA specification for SAS dated January 19, 1979

The line control procedure for the teletype circuits is significantly different from Bell 83B3 polled protocol as it is a customized one of a kind procedure that is based upon an

hourly schedule. Although SAS protocol is standard ANSI X3.28-1976, Category X2.7 is chosen to facilitate distribution of large volumes of data in a broadcast node. Conversely these control procedures also allow users a means of supplying reports to the WMSC data base and/or selectively requesting reports from the database.

A.3 NODAL LOCATIONS AND FACILITY IDENTIFICATION

All node locations are to be identified by Vertical and Horizontal grid coordinates, the facility type, and the ARTCC area the facility belongs to. Appendix C presents each ARTCC and the nodes that are within the confines of its area of responsibility. Appendix D presents the same nodal population sorted by nodal type.

A.4 TERMINALS

Area A terminals are located predominantly at Flight Service Stations although other FAA facilities that input data or receive broadcasts are also in the population. Request/Reply terminals are used for flight briefing purposes and therefore most of these terminals are at FSS's with a small percentage at other FAA facilities. The dedicated ARTCC circuit terminations are located exclusively at ARTCC's. Figure A-1 reflects the distribution of service node population by facility.

A.5 CLUSTER TERMINALS

SAS nodes are located exclusively at FSS sites. Figure A-2 shows the SAS location distribution per ARTCC.

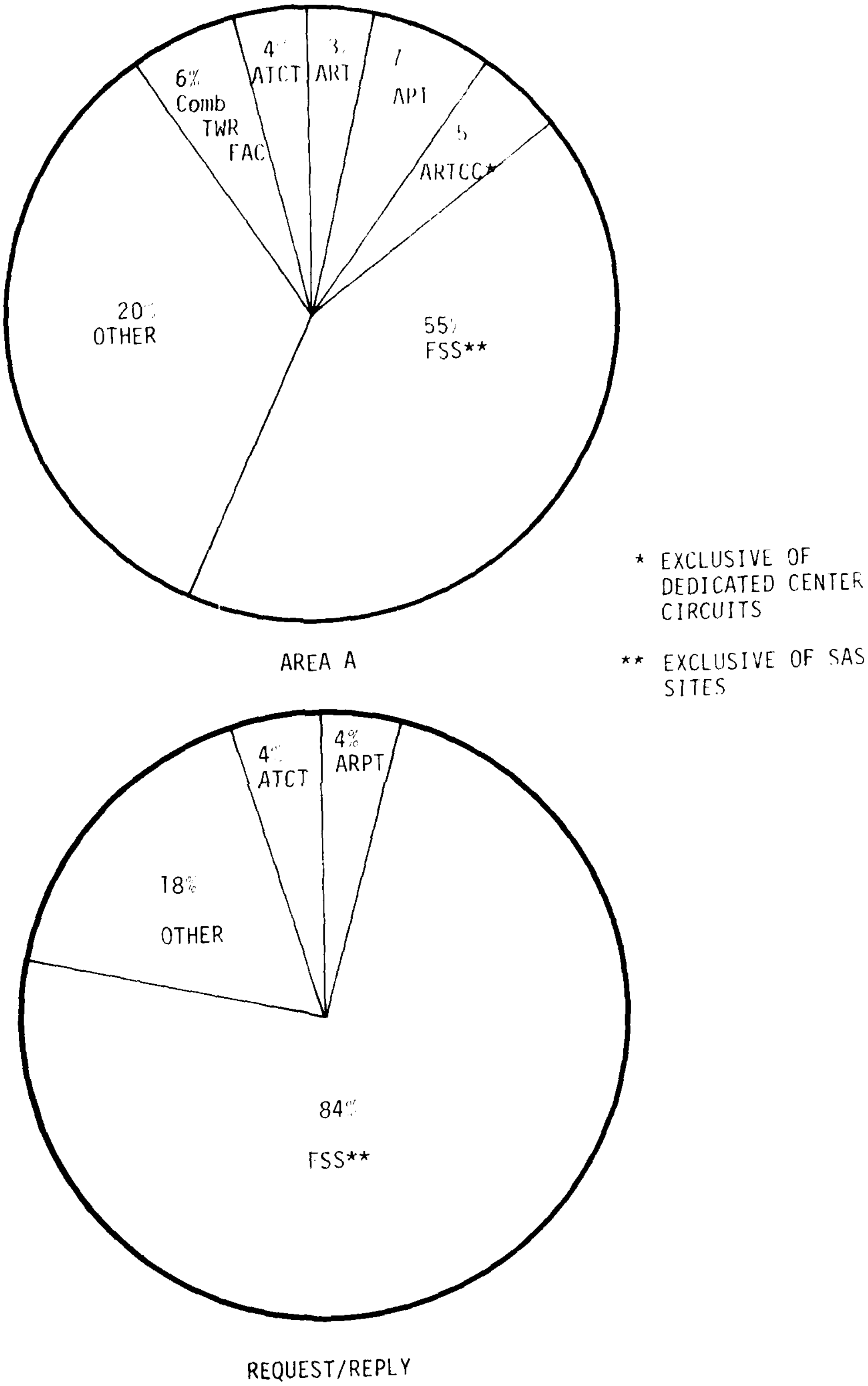
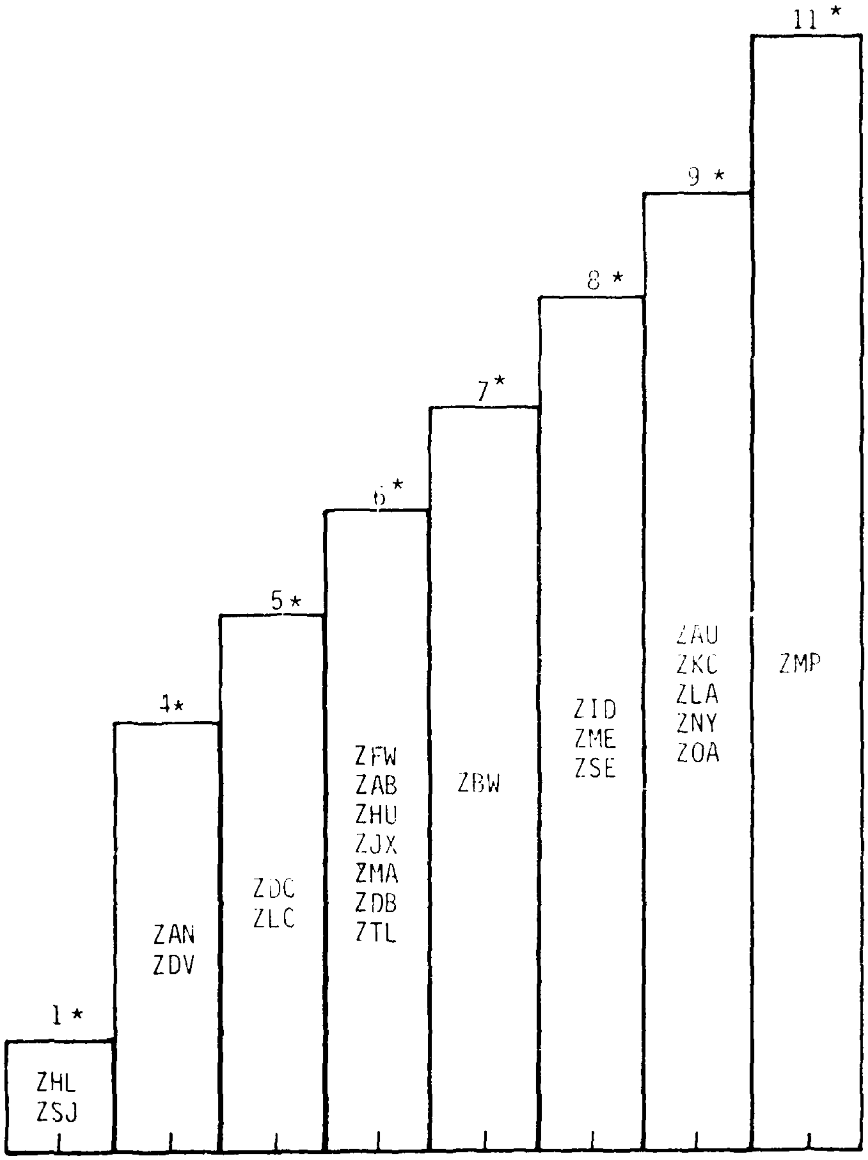


FIGURE A-1: NODE POPULATION DISTRIBUTION BY FACILITY TYPE



* Number of SAS sites per ARTCC.

FIGURE A-2: SAS LOCATION DISTRIBUTION BY ARTCC

Present Value Factor (PVF) for N month cycle, with monthly compounding and monthly interest I = .008333.

$$PVF = \frac{(1+I)^N - 1}{I(1+I)^N}$$

No. of Months = N	PVF
12	11.4
24	21.4
36	31
48	39.4
60	47.1
72	54
84	60.2
96	65.9
108	71.0
120	75.7

TABLE A.1: PRESENT VALUE FACTOR

APPENDIX B

SERVICE A CIRCUIT SUMMARY PROJECTED FOR 1982 WITHOUT NADIN

AREA CIRCUIT	AREA SERVED	AREA CIRCUIT	AREA SERVED
1	ME, NH, VT, MA	24	SD, ND, MN
2	NY, NJ, CT, MA	25	MT, ND, SD
3	NY, PA	26	NE
4	PA, NY	27	CO, WY, NE
5	DC, VA, PA, MD, NJ	28	KS, TX, CO
6	WV, OH	29	TX, OK
7	NC, VA, WV	30	NM, TX
8	SC, NC	31	MT
9	GA, FL	32	ID, OR, WA, WY
10	FL	33	UT, WY, CO, NM
11	MI	34	NV, CA
12	OH, PA	35	AZ, CA
13	IN, IL, MI	36	WA, ID
14	TN, KY	37	OR, WA
15	AL, FL, GA, MS	38	CA
16	MI, WI, MN	39	CA
17	WI, IA, MN	40	CA
18	IL, MO, IA	41	AK
19	KS, MO	42	AK
20	AR, TN, MS	43	AK
21	OK, TX	44	AK
22	MS, LA, AL, TX	45	AK
23	TX, LA		

TABLE B.1: AREAS OF SERVICE FOR CURRENT AREA & R/R CIRCUITS

FAC6514	ICT	Wichita, KS	11	ACE
	OKC	Oklahoma City, OK	13	ASW
	HOU	Houston, TX	11	ASW
	DAL	Dallas, TX	9	ASW
	TUL	Tulsa, OK	9	ASW
	FTW	Fort Worth, TX	8	ASW
	SHV	Shreveport, LA	7	ASW
	SAT	San Antonio, TX	9	ASW
	AUS	Austin, TX	8	ASW
FAC6515	LOU	Louisville, KY	8	ASO
	MBS	Siginaw, MI	8	AGL
	FDX	Findlay, OH	10	AGL
	DET	Detroit, MI	16	AGL
	DAY	Dayton, OH	12	AGL
	CMH	Columbus, OH	12	AGL
	LUK	Cincinnati, OH	12	AGL
	FWA	Fort Wayne, IN	8	AGL
	CLE	Cleveland, OH	14	AGL
FAC6516	CHI	Chicago, IL	17	AGL
	SBN	South Bend, IN	12	AGL
	MKE	Milwaukee, WI	13	AGL
	HUF	Terre Haute, IN	8	AGL
	GRB	Green Bay, WI	8	AGL
	LFT	Lafayette, IN	8	AGL
	AUW	Wausau, WI	8	AGL
	RFD	Rockford, IL	7	AGL
FAC6517	MSP	Minneapolis, MN	15	AGL
	CID	Cedar Rapids, IA	8	ACE
	DSM	Des Moines, IA	9	ACE
	MCW	Mason City, IA	5	ACE
	GFK	Grand Forks, ND	6	ARM
	BRL	Burlington, IA	6	ACE
	HIB	Hibbing, MN	10	AGL
	AXN	Alexandria, MN	8	AGL
	RWF	Redwood Falls, MN	6	AGL
FAC6518	HNL	Honolulu, HI	12	APC

Table B-2 LEASED SERVICE A SYSTEM CIRCUITS (Cont'd)

FAC6510	HKY	Hickory, NC	10	ASO
	BNA	Nashville, TN	8	AWO
	SAV	Savannah, GA	7	ASO
	TYS	Knoxville, TN	5	ASO
	FLO	Florence, SC	8	ASO
	CSV	Crossville, TN	7	ASO
	GSP	Greer, SC	8	ASO
	LOZ	London, KY	6	ASO
	CHS	Charleston, SC	8	ASO
	BWG	Bowling Green, KY	7	ASO
FAC6511	RDU	Raleigh-Durham, NC	11	ASO
	PHF	Newport News, VA	5	AEA
	ROA	Roanoke, VA	6	AEA
	EWN	New Bern, NC	6	ASO
	SBY	Salisbury, MD	4	AEA
	PKB	Parkersburg, WV	3	AEA
	MRB	Martinsburg, WV	4	AEA
	BLF	Bluefield, WV	3	AEA
	CRW	Charleston, WV	6	AEA
FAC6512	ALB	Albany, NY	5	AEA
	BOS	Boston, MA	11	ANE
	AUG	Augusta, ME	4	ANE
	BDL	Windsor Locks, CT	9	ANE
	BUF	Buffalo, NY	8	AEA
	ELM	Elmira, NY	4	AEA
	CON	Concord, NH	4	ANE
	UCA	Utica, NY	4	AEA
	MPV	Montpelier, VT	5	ANE
FAC6513	MEM	Memphis, TN	10	ASO
	MOB	Mobile, AL	6	ASO
	NEW	New Orleans, LA	9	ASW
	BHM	Birmingham, AL	9	ASO
	ANB	Anniston, AL	6	ASO
	MSL	Muscle Shoals, AL	6	ASO
	LIT	Little Rock, AR	8	ASW
	JAN	Jackson, MS	8	ASO
	GWO	Greenwood, MS	6	ASO

Table B-2 LEASED SERVICE A SYSTEM CIRCUITS (Cont'd)

FAC6505	PDX	Portland, OR	13	ANW
	GTF	Great Falls, MT	5	ARM
	RDM	Redmond, OR	7	ANW
	ALW	Walla Walla, WA	10	ANW
	BOI	Boise, ID	10	ANW
	SFF	Spokane, WA	6	ANW
	OTH	North Bend, OR	7	ANW
	EAT	Wenatchee, WA	6	ANW
	SEA	Seattle, WA	13	ANW
	BLI	Bellingham, WA	6	ANW
FAC6506	MKC	Kansas City, MO	14	ACE
	STL	St. Louis, MO	14	ACE
FAC6506	COU	Columbia, MO	6	ACE
	CGI	Cape Girardeau, MO	6	ACE
	DEC	Decatur, IL	12	AGL
	SGF	Springfield, MO	7	ACE
	UIN	Quincy, IL	8	AGL
	CNU	Chanute, KS	4	ACE
FAC6507	ANC	Anchorage, AK	12	AAL
	FAI	Fairbanks, AK	10	AAL
	BET	Bethel, AK	5	AAL
	ENA	Kenai, AK	4	AAL
FAC6508	FAT	Fresno, CA	6	AWE
	OAK	Oakland, CA	13	AWE
	RBL	Red Bluff, CA	7	AWE
	SAC	Sacramento, CA	8	AWE
	SCK	Stockton, CA	4	AWE
	SNS	Salinas, CA	5	AWE
	UKI	Ukiah, CA	5	AWE
	PRB	Paso Robles, CA	5	AWE
	RNO	Reno, NV	7	AWE
FAC6509	SBA	Santa Barbara, CA	7	AWE
	LAS	Las Vegas, NV	9	AWE
	LAX	Los Angeles, CA	15	AWE
	SAN	San Diego, CA	8	AWE
	WJF	Lancaster, CA	5	AWE
	ONT	Ontario, CA	9	AWE
	BFL	Bakersfield, CA	3	AWE
	TRM	Thermal, CA	4	AWE
	IPL	Imperial, CA	3	AWE

Table B-2 LEASED SERVICE A SYSTEM CIRCUITS (Cont'd)

CIRCUIT	LOCATION I.D.	FACILITY	KVDTs	REGION
FAC6501	SLC	Salt Lake City, UT	11	ARM
	HON	Huron, SD	6	ARM
	LBF	North Platte, NE	5	ACE
	DEN	Denver, CO	11	ARM
	OMA	Omaha, NE	10	ACE
	GJT	Grand Junction, CO	5	ARM
	CPR	Casper, WY	5	ARM
	GRI	Grand Island, NE	5	ACE
	LNK	Lincoln, NE	5	ACE
	BYI	Burley, ID	6	ANW
FAC6502	MIA	Miami, FL	20	ASO
	SJU	San Juan, PR	7	ASO
	PIE	St. Petersburg, FL	10	ASO
	ORL	Orlando, FL	8	ASO
	JAX	Jacksonville, FL	6	ASO
	VRB	Vero Beach, FL	7	ASO
	FMY	Fort Myers, FL	6	ASO
	GNV	Gainesville, FL	6	ASO
	MLB	Melborne, FL	6	ASO
	TLH	Tallahassee, FL	5	ASO
FAC6503	PHX	Phoenix, AZ	12	AWE
	ELP	El Paso, TX	7	ASW
	ABQ	Albuquerque, NM	7	ASW
	PRC	Prescott, AZ	4	AWE
	GCK	Garden City, KS	5	ACE
	TUS	Tucson, AZ	6	AWE
	AMA	Amarillo, TX	5	ASW
	MAF	Midland, TX	4	ASW
FAC6504	ISP	Islip, NJ	8	AEA
	POU	Poughkeepsie, NY	5	AEA
	PNE	Philadelphia, PA	7	AEA
	MIV	Millville, NJ	6	AEA
	TEB	Teterboro, NJ	10	AEA
	HAR	Harrisburg, PA	6	AEA
	AGC	Pittsburgh, PA	8	AEA
	AVP	Wilkes Barre, PA	3	AEA

Table B-2 LEASED SERVICE A SYSTEM CIRCUITS

APPENDIX C

NODAL LOCATION BY ARTCC

C.1 This appendix presents nodes by type, facility, location of node, transmission mode (HD, FD, or RO), city, and state.

C.2 A summary for each ARTCC is also presented which shows the number of each type of node in the ARTCC area.

C.3 Node type consists of the three letter location designator and a subscript which describes the node type as follows:

LID-S	:	SAS Node
LID-A	:	Area A Node
LID-R	:	Request/Reply Node
LID-Z	:	ARTCC Service A Node

C.4 Some locations have multiple terminals of the same type. In this case a number designator is used as follows:

LID1A
LID2A

ARTCC : ZAB

DUG-R	FSS	HD	DOUGLAS	AZ
DUG-A	FSS	HD	DOUGLAS	AZ
FHU-A	AAF	HD	LIBBY AAF	AZ
PGA-A	AMOS?5	RO	PAGE	AZ
PHX-S	FSS	FD	PHOENIX	AZ
PRC-S	FSS	FD	PRESCOTT	AZ
TUS-S	FSS	FD	TUCSON	AZ
INW-R	APT	HD	WINSLOW	AZ
ABQ-S	FSS	FD	ALBUQUERQUE	NM
ZAB-Z	ARTCC	FD	ALBUQUERUE	NM
CNM-R	FSS	HD	CARLSBAD	NM
CNM-A	FSS	HD	CARLSBAD	NM
CAO2A	AMOS?W	RO	CLAYTON	NM
CAO3A	APT	HD	CLAYTON	NM
CAO1A	AMOS?W	HD	CLAYTON	NM
DMN-R	FSS	HD	DEMING	NM
DMN-A	FSS	HD	DEMING	NM
GUP-R	FSS	HD	GALLUP	NM
GUP-A	FSS	HD	GALLUP	NM
GNT-R	APT	HD	GRANTS	NM
GNT-A	APT	HD	GRANTS	NM
LVS-R	FSS	HD	LAS VEGAS	NM
LVS-A	FSS	HD	LAS VEGAS	NM
ROW-R	FSS	HD	ROSWELL	NM
ROW-A	FSS	HD	ROSWELL	NM
SAF-R	ATCT	HD	SANTA FE	NM
SAF-A	ATCT	RO	SANTE FE	NM
TCS-R	FSS	HD	TRUTH OR CONSEQ	NM
TCS-A	FSS	HD	TRUTH OR CONSEQ	NM
TCC-R	FSS	HD	TUCUMCARI	NM
TCC-A	FSS	HD	TUCUMCARI	NM
AMA-S	FSS	FD	AMARILLO	TX
DHT-R	FSS	HD	DALHART	TX
DHT-A	FSS	HD	DALHART	TX
ELP-S	FSS	FD	EL PASO	TX
MRF-A	AMOS?B	HD	MARFA	TX

SUMMARY SAS : 6
AREA A : 17
R/R : 12
CNTR : 1

ARTCC : ZAN

ADK-A	FSS	HD	ADAK	AK
ADK-R	FSS	HD	ADAK	AK
ZAN-Z	ARTCC	FD	ANCHORAGE	AK
ANC-A	ARTS	RO	ANCHORAGE	AK
ANC-S	FSS	FD	ANCHORAGE	AK
ANI-A	FSS	HD	ANIAK	AK
ANI-R	FSS	HD	ANIAK	AK
ANN-A	RCO	HD	ANNETTE ISLAND	AK
OAN-A	RCO	HD	ANVIL MOUNTAIN	AK
BRW1A	FSS	HD	BARROW	AK
BRW2A	FSS	RO	BARROW	AK
BRW-R	FSS	HD	BARROW	AK
BET-S	FSS	FD	BETHEL	AK
CDV-A	FSS	HD	CORDOVA	AK
CDV-R	FSS	HD	CORDOVA	AK
SCC-R	FSS	HD	DEADHORSE	AK
SCC-A	FSS	HD	DEADHORSE	AK
FAI-S	FSS	FD	FAIRBANKS	AK
FAI-A	ARTS	HD	FAIRBANKS	AK
HOM-R	FSS	HD	HOMER	AK
HOM1A	FSS	HD	HOMER	AK
HOM2A	FSS	RO	HOMER	AK
JNU2A	FSS	RO	JUNEAU	AK
JNU-R	FSS	HD	JUNEAU	AK
JNU1A	FSS	HD	JUNEAU	AK
ENA-S	FSS	FD	KENAI	AK
KTN3A	FSS	RO	KETCHIKAN	AK
KTN2A	FSS	RO	KETCHIKAN	AK
KTN1A	FSS	HD	KETCHIKAN	AK
KTN-R	FSS	HD	KETCHIKAN	[illegible]
ADQ-R	FSS	HD	KODIAK	[illegible]
ADQ-A	FSS	HD	KODIAK	[illegible]
OTZ-R	FSS	HD	KOTZEBUE	AK
OTZ-A	FSS	HD	KOTZEBUE	AK
MGC-A	FSS	HD	MCGRATH	AK
MGC-R	FSS	HD	MCGRATH	AK
MDO-A	RCO	HD	MIDDLETON ISLAND	AK
OME1A	FSS	HD	NOME	AK
OME-R	FSS	HD	NOME	AK
OME2A	FSS	RO	NOME	AK
OME3A	FSS	RO	NOME	AK
ORT-R	FSS	HD	NORTHWAY	AK
ORT2A	FSS	RO	NORTHWAY	AK
ORT1A	FSS	HD	NORTHWAY	AK
PAQ-A	FSS	HD	PALMER	AK
PAQ-R	FSS	HD	PALMER	AK
SIT-R	FSS	HD	SITKA	AK
SIT2A	FSS	RO	SITKA	AK
SIT1A	FSS	HD	SITKA	AK
SIT3A	FSS	RO	SITKA	AK
VDZ-A	CST	HD	VALDEZ	AK
YAK3A	FSS	RO	YAKUTAT	AK
YAK2A	FSS	RO	YAKUTAT	AK
YAK-R	FSS	HD	YAKUTAT	AK
YAK1A	FSS	HD	YAKUTAT	AK

SUMMARY GAS : 4
AREA A : 34
R/R : 16
CNTR : 1

ARTCC : ZAU

BRL-S	FSS	FD	BURLINGTON	IA
CID-S	FSS	FD	CEDAR RAPIDS	IA
OTM-R	FSS	HD	OTTUMWA	IA
OTM-A	FSS	HD	OTTUMWA	IA
CHI-S	FSS	FD	CHICAGO	IL
ZAU-Z	ARTCC	FD	CHICAGO	IL
ZAU-A	ARTCC	RG	CHICAGO	IL
AGC-A	COMCO	HD	DES PLAINE	IL
PIA-R	TRACC	HD	PEORIA	IL
PIA-A	ARPT	HD	PEORIA	IL
RFD-S	FSS	FD	ROCKFORD	IL
FWA-S	FSS	FD	FORT WAYNE	IN
SBN-S	FSS	FD	SOUTH BEND	IN
BTL-A	TWRPLA	RG	BATTLE CREEK	MI
BTL-A	ATCT	RG	BATTLE CREEK	MI
GRB-S	FSS	FD	GREENBAY	WI
LNR-R	FSS	HD	LONE ROCK	WI
LNR-A	FSS	HD	LONE ROCK	WI
MKE-S	FSS	FD	MILWAUKEE	WI
AUW-S	FSS	FD	WAUSAU	WI

SUMMARY SAS : 9
AREA A : 7
B/R : 3
CNTR : 1

ARTCC : ZBW

BDL-S	FSS	FD	WINDSOR LOCKS	CT
BED-A	ARPT	RO	BEDFORD	MA
BED-A	TWR?LA	HD	BEDFORD	MA
BOS-S	FSS	FD	BOSTON	MA
RBN-A	COMCO	RO	BURLINGTON	MA
ACK-A	ATCT	RO	NANTUCKET	MA
FMH-A	CGAS	RO	OTIS AFB	MA
PSF-A	APT	RO	PITTSFIELD	MA
ORH2A	ATCT	RO	WORCESTER	MA
ORH1A	AMOS?W	RO	WORCESTER	MA
ORH-R	ATCT	HD	WORCESTER	MA
AUG-S	FSS	FD	AUGUSTA	ME
BGR-A	FSS	HD	BANGOR	ME
BGR-R	FSS	HD	BANGOR	ME
6B2-A	AMOS	HD	GREENVILLE	ME
HUL-R	FSS	HD	HOULTON	ME
HUL-A	FSS	HD	HOULTON	ME
OLD-A	AID	RO	OLD TOWN	ME
ZBW-A	ARTCC	RO	BOSTON	NH
ZBW-Z	ARTCC	FD	BOSTON	NH
CON-S	FSS	FD	CONCORD	NH
LCI-A	APT	RO	LACONIA	NH
LEB-A	FSS	HD	LEBANON	NH
LEB-R	FSS	HD	LEBANON	NH
ALB-S	FSS	FD	ALBANY	NY
GFL-A	FSS	HD	GLEN FALLS	NY
GFL-R	FSS	HD	GLEN FALLS	NY
MSS-A	FSS	HD	MASSENA	NY
MSS-R	FSS	HD	MASSENA	NY
UCA-S	FSS	FD	UTICA	NY
ART-R	FSS	HD	WATERTOWN	NY
ART-A	FSS	HD	WATERTOWN	NY
PVD-A	ATCT	RO	PROVIDENCE	RI
BTV-R	ARPT	HD	BURLINGTON	VT
BTV-A	ARPT	RO	BURLINGTON	VT
MPV-S	FSS	FD	MONTPELIER	VT

SUMMARY SAS : 7
AREA A : 20
R/R : 8
CNTR : 1

ARTCC : ZDC

DCA1A	ARTS	RG	WASHINGTON	DC
RWA-A	COMCO	HD	WASHINGTON	DC
ZDC-Z	ARTCC	FD	WASHINGTON	DC
DCA-R	FSS	HD	WASHINGTON	DC
DCA2A	ARTS	RG	WASHINGTON	DC
ZDC-A	ARTCC	RG	WASHINGTON	DC
ECG-A	FSS	HD	ELIZABETH	NC
ECG-R	FSS	HD	ELIZABETH CITY	NC
W72-A	APT	HD	HATTERAS	NC
EWN-S	FSS	FD	NEW BERN	NC
RDU-S	FSS	FD	RALEIGH-DURHAM	NC
RWI-R	FSS	HD	ROCKY MOUNT	NC
RWI-A	FSS	HD	ROCKY MOUNT	NC
ILM-R	ARPT	HD	WILMINGTON	NC
IAD-A	ARTS	RG	CHANTILLY	VA
DAN-R	FSS	HD	DANVILLE	VA
DAN-A	FSS	HD	DANVILLE	VA
PHF-S	FSS	FD	NEWPORT NEWS	VA
NGU-A	NAS?AW	HD	NORFOLK NAS	VA
ROA-S	FSS	FD	ROANOKE	VA
EKN-R	FSS	HD	ELKINS	WV
EKN-A	FSS	HD	ELKINS	WV
MRB-S	FSS	FD	MARTINSBURG	WV
RWH-A	COMCO	HD	MARTINSBURG	WV

SUMMARY SAS : 5
AREA A : 12
R/R : [illegible]
CNTR : 1

ARTCC : ZDV

AKO-A	FSS	HD	AKRON	CO
AKO-R	FSS	HD	AKRON	CO
RDE-A	COMCO	HD	AURORA	CO
DEN-S	FSS	FD	DENVER	CO
ZDV-A	ARTCC	FD	DENVER	CO
ZDV-Z	ARTCC	FD	DENVER	CO
EGE-A	FSS	HD	EAGLE	CO
EGE-R	FSS	HD	EAGLE	CO
GJT-S	FSS	FD	GRAND JUNCTION	CO
BJC-A	TWR2LA	FD	JEFFCO	CO
LHX-A	FSS	HD	LA JUNTA	CO
LHX-R	FSS	HD	LA JUNTA	CO
PUE-A	TRCAB	HD	PUEBLO	CO
PUB-R	TRCAB	HD	PUEBLO	CO
TAD-A	FSS	HD	TRINIDAD	CO
TAD-R	FSS	HD	TRINIDAD	CO
GLD-A	FSS	HD	GOODLAND	KS
GLD-R	FSS	HD	GOODLAND	KS
HLC-R	FSS	HD	HILL CITY	KS
HLC-A	FSS	HD	HILL CITY	KS
CDR-A	FSS	HD	CHADRON	NE
CDR-R	FSS	HD	CHADRON	NE
LBF-S	FSS	FD	NORTH PLATTE	NE
BFF-A	FSS	HD	SCOTTSBLUFF	NE
BFF-R	FSS	HD	SCOTTSBLUFF	NE
SNY-R	FSS	HD	SIDNEY	NE
SNY-A	FSS	HD	SIDNEY	NE
CHB-A	AMOS	HD	CHAMBERLAIN	SD
RAP-A	FSS	HD	RAPID CITY	SD
RAP-R	FSS	HD	RAPID CITY	SD
CPR-S	FSS	FD	CASPER	WY
LAR-A	FSS	HD	LARAMIE	WY
LAR1R	FSS	HD	LARAMIE	WY
LAR2R	FSS	HD	LARAMIE	WY

SUMMARY SAS : 4
AREA A : 16
R/R : 13
CNTR : 1

ARTCC : ZFW

ELD-R	FSS	HD	EL DORADO	AR
ELD-A	FSS	HD	EL DORADO	AR
MLU-R	FSS	HD	MONROE	LA
MLU-A	FSS	HD	MONROE	LA
SHV-S	FSS	FD	SHREVEPORT	LA
HBR-R	FSS	HD	HOBART	OK
HBR-A	FSS	HD	HOBART	OK
MLC-R	FSS	HD	MCALESTER	OK
MLC-A	FSS	HD	MCALLSTER	OK
OEX-R	AEROCT	HD	OKLAHOMA CITY	OK
OKC-S	FSS	FD	OKLAHOMA CITY	[illegible]
OKC-A	ATCT	RD	OKLAHOMA CITY	OK
TUL-S	FSS	FD	TULSA	OK
RVS-A	LAWRS	HD	TULSA-RIVERSIDE	OK
ABI-R	FSS	HD	ABILENE	TX
ABI-A	FSS	HD	ABILENE	TX
CDS-R	FSS	HD	CHILDRESS	TX
CDS-A	FSS	HD	CHILDRESS	TX
DAL-S	FSS	FD	DALLAS	TX
ZFW-Z	ARTCC	FD	FORT WORTH	TX
FTW-S	FSS	FD	FORT WORTH	TX
ZFW-A	ARTCC	RD	FORT WORTH	TX
LBB-R	FSS	HD	LUBBOCK	TX
LBB-A	FSS	HD	LUBBOCK	TX
MAF-S	FSS	FD	MIDLAND	TX
MWL-R	FSS	HD	MINERAL WELLS	TX
MWL-A	FSS	HD	MINERAL WELLS	TX
SJT-R	ATCT	HD	SAN ANGELO	TX
SPS-R	FSS	HD	WICHITA FALLS	TX
SPS-A	FSS	HD	WICHITA FALLS	TX
INK-R	FSS	HD	WINK	TX
INK-A	FSS	HD	WINK	TX

SUMMARY TAB : [illegible]
AREA C : 1[illegible]
R/R : 1[illegible]
CNTR : 1

ARTCC : ZHL

HNL-S	FSS	PI	HONOLULU	HI

SUMMARY SAC : 1
AREA A : 0
R/F : 0
CNTR : 0

ARTCC : ZHU

MOB-S	FSS	HD	MOBILE	AL
BTR-R	TRACO	HD	BATON ROUGE	LA
ESF-R	FSS	HD	[illegible]	LA
ESF-A	FSS	HD	ESLER FIELD	LA
LFT-A	FSS	HD	LAFAYETTE	LA
LFT-R	FSS	HD	LAFAYETTE	LA
LCH-R	FSS	HD	LAKE CHARLES	LA
LCH-A	FSS	HD	LAKE CHARLES	[illegible]
NEW-S	FSS	FD	NEW ORLEANS	LA
NEW-A	TRWPLA	HD	NEW ORLEANS-LAK	LA
MCB-A	FSS	HD	MCCOMB	MS
MCB-R	FSS	HD	MCCOMB	MS
ALI-A	FSS	HD	ALICE	TX
ALI-R	FSS	HD	ALICE	TX
AUS-S	FSS	FD	AUSTIN	TX
BPT-A	ARPT	HD	BEAUMONT	TX
BRO-A	ATCT	HD	BROWNSVILLE	TX
CLL-A	FSS	HD	COLLEGE STATION	TX
CLL-R	FSS	HD	COLLEGE STATION	TX
COT-A	FSS	HD	COTULLA	TX
COT-R	FSS	HD	COTULLA	TX
DRT-A	APT	HD	DEL RIO	TX
GLS2A	FSS	HD	GALVESTON	TX
GLS-R	FSS	HD	GALVESTON	TX
GLS-A	AMOSCF	RD	GALVESTON	TX
HOU-S	FSS	FD	HOUSTON	TX
ZHU-A	ARTCC	RD	HOUSTON	TX
ZHU-Z	ARTCC	FD	HOUSTON	TX
HOU-A	TRCAB	HD	HOUSTON-HOBBY	TX
LFK-A	FSS	HD	LUFKIN	TX
LFK-R	FSS	HD	LUFKIN	TX
MFE-A	FSS	HD	MCALLEN	TX
MFE-R	FSS	HD	MCALLEN	TX
PSX-A	FSS	HD	PALACIOS	TX
PSX-R	FSS	HD	PALACIOS	TX
SAT-S	FSS	FD	SAN ANTONIO	TX
SSF-A	LAWRS	HD	SAN ANTONIO-STI	TX
SSF-A	LAWRS	HD	SAN ANTONIO-STI	TX

SUMMARY SAS : 5
AREA A : 20
R/R : 12
CNTR : 1

ARTCC : ZID

IND-R	FSS	HD	INDIANAPOLIS	IN
ZID-Z	ARTCC	FI	INDIANAPOLIS	IN
ZID-A	ARTCC	AL	INDIANAPOLIS	IN
IND-A	FSS	HD	INDIANAPOLIS	IN
LAF-S	FSS	FI	LAFAYETTE	IN
HUF-S	FSS	FD	TERRE HAUTE	IN
LOZ-S	FSS	FI	LONDON	KY
LOU-S	FSS	FI	LOUISVILLE	KY
LUK-S	FSS	FD	CINCINNATI	OH
CMH-S	FSS	FD	COLUMBUS	OH
OSU-A	LAWRS	FO	COLUMBUS	OH
DAY-S	FSS	FD	DAYTON	OH
ZZV2R	FSS	HD	ZANESVILLE	OH
ZZV1R	FSS	HD	ZANESVILLE	OH
ZZV-A	FSS	HD	ZANESVILLE	OH
CRW-S	FSS	FD	CHARLESTON	WV
HTS-R	FSS	HI	HUNINGTON	WV
HTS-A	FSS	HI	HUNTINGTON	WV
PKB-S	FSS	FD	PARKERSBURG	WV

SUMMARY SAS : 9
AREA A : 5
R/R : 4
CNTR : 1

ARTCC : ZJX

DHN-R	FSS	HD	DOTHAN	AL
DHN-A	FSS	HD	DOTHAN	AL
CEW-R	FSS	HD	CRESTVIEW	FL
CEW-A	FSS	HD	CRESTVIEW	FL
CTY-A	APT	HD	CROSS CITY	FL
GNV-S	FSS	FD	GAINESVILLE	FL
JAX-S	FSS	FD	JACKSONVILLE	FL
ZJX-Z	ARTCC	FD	JACKSONVILLE	FL
PNS-R	FSS	HD	PENSACOLA	FL
PNS-A	FSS	HD	PENSACOLA	FL
TLH-S	FSS	FD	TALLAHASSEE	FL
ABY-R	FSS	HD	ALBANY	GA
ABY-A	FSS	HD	ALBANY	GA
AMG-R	FSS	HD	ALMA	GA
AMG-A	FSS	HD	ALMA	GA
SSI-R	FSS	HD	BRUNSWICK	GA
SSI-A	FSS	HD	BRUNSWICK	GA
SAV-S	FSS	FD	SAVANNAH	GA
VLD-R	FSS	HD	VALDOSTA	GA
VLD-A	FSS	HD	VALDOSTA	GA
ILM-A	ARPT	RO	WILMINGTON	NC
CHS-S	FSS	FD	CHARLESTON	SC
FLO-S	FSS	FD	FLORENCE	SC
CRE-R	FSS	HD	NORTH MYRTLE BE	SC
CRE-A	FSS	HD	NORTH MYRTLE BE	SC

SUMMARY SAT : 6
AREA A : 10
R/R : 8
CNTR : 1

ARTCC : ZKC

DEC-S	FSS	FD	DECATUR	IL
UIN-S	FSS	FD	QUINCY	IL
CNU-S	FSS	FD	CHANUTE	KS
DDC-R	FSS	HD	DODGE CITY	KS
DDC-A	FSS	HD	DODGE CITY	KS
EMP-A	FSS	HD	EMPORIA	KS
EMP-R	FSS	HD	EMPORIA	KS
GCK-S	FSS	FD	GARDEN CITY	KS
ZKC-A	ARTCC	RD	KANSAS CITY	KS
ZKC-A	ARTCC	RD	KANSAS CITY	KS
MHK-A	FSS	HD	MANHATTAN	KS
MHK-R	FSS	HD	MANHATTAN	KS
RSL-R	FSS	HD	RUSSELL	KS
RSL-A	FSS	HD	RUSSELL	KS
SLN-R	FSS	HD	SALINA	KS
SLN-A	FSS	HD	SALINA	KS
ICT-S	FSS	FD	WICHITA	KS
COU-S	FSS	FD	COLUMBIA	MO
JLN-R	FSS	HD	JOPLIN	MO
JLN-A	FSS	HD	JOPLIN	MO
MKC-S	FSS	FD	KANSAS CITY	MO
SGF-S	FSS	FD	SPRINGFIELD	MO
STL-S	FSS	FD	ST. LOUIS	MO
VIH-R	FSS	HD	VICHY	MO
VIH-A	FSS	HD	VICHY	MO
GAG-R	FSS	HD	GAGE	OK
GAG-A	FSS	HD	GAGE	OK
PNC-R	FSS	HD	PONCA CITY	OK
PNC-A	FSS	HD	PONCA CITY	OK

SUMMARY SAS : 9
AREA A : 11
R/R : 9
CNTR : 0

ARTCC : ZLA

IGM-A	AMOS	HD	KINGMAN	AZ
YUM-R	FSS	HD	YUMA	[illegible]
YUM-A	FSS	HD	YUMA	[illegible]
BFL-[illegible]	FSS	FD	BAKERSFIELD	CA
BLH-[illegible]	FSS	HD	BLYTHE	CA
BLH-R	FSS	HD	BLYTHE	CA
[illegible]	ART	[illegible]	CALEXICO	CA
DAG-R	FSS	HD	DAGGETT	[illegible]
DAG-A	FSS	HD	DAGGETT	CA
FCH-A	TWRLA	[illegible]	FRESNO-CHANDLER	CA
FUL-R	FSS	HD	FULLERTON	CA
FUL-A	FSS	HD	FULLERTON	CA
FUL-R	FSS	HD	FULLERTON	CA
IPL-[illegible]	[illegible]	FD	IMPERIAL	CA
WJF-[illegible]	FSS	RD	LANCASTER	CA
LAX-S	FSS	FD	LOS ANGELES	CA
ZLA-A	ARTCC	RD	LOS ANGELES	CA
ZLA-Z	ARTCC	FD	LOS ANGELES	CA
LAX-A	ARTS	RD	LOS ANGELES	CA
ZLA-A	ARTCC	RD	LOS ANGELES	CA
RLA-A	COMCO	HD	LOS ANGELES	CA
RIV-A	AFBRAW	RD	MARCH AFB	CA
EED-R	FSS	HD	NEEDLES	CA
EED-A	FSS	RD	NEEDLES	CA
SBD-A	AFB	FD	NORTON AFB	CA
ONT-S	FSS	FD	ONTARIO	[illegible]
PMD-A	TWRLA	RD	PALMDALE	CA
PMD-A	TWRLA	RD	PALMDALE	CA
RAL-A	TWRLA	[illegible]	RIVERSIDE	CA
SAN-S	FSS	FD	SAN DIEGO	CA
SAN-A	ATCT	RD	SAN DIEGO	CA
SNA1A	FSS	RD	SANTA ANA	CA
SNA2A	FSS	RD	SANTA ANA	CA
SBA-S	FSS	FD	SANTA BARBARA	CA
SMX-R	ATCT	HD	SANTA MARIA	CA
TRM-S	FSS	FD	THERMAL	[illegible]
LAS-S	FSS	FD	LAS VEGAS	NV
BCE-A	FSS	HD	BRYCE	UT
BCE-R	FSS	HD	BRYCE CANYON	UT
CDC-R	FSS	HD	CEDAR CITY	UT
CDC-A	FSS	HD	CEDAR CITY	UT
WRL-R	FSS	HD	WORLAND	WY

SUMMARY SAS : [illegible]
AREA A : 22
R/R : 19
CNTR : 1

ARTCC : ZLC

BOI-S	FSS	FD	BOISE	ID
BYI-S	FSS	FD	BURLEY	ID
IDA-R	FSS	HD	IDAHO FALLS	ID
IDA-A	FSS	HD	IDAHO FALLS	ID
BIL-R	FSS	HD	BILLINGS	MT
BIL-A	FSS	HD	BILLINGS	MT
BIL-A	FSS	FD	BILLINGS	MT
BZN-R	FSS	HD	BOZEMAN	MT
BZN-A	FSS	HD	BOZEMAN	MT
BTM-R	FSS	HD	BUTTE	MT
BTM-A	FSS	HD	BUTTE	MT
CTB-A	FSS	HD	CUT BANK	MT
CTB-R	FSS	HD	CUT BANK	MT
GTF-S	FSS	FD	GREAT FALLS	MT
GTF-A	ATCT	HD	GREAT FALLS	MT
LWT-R	FSS	HD	LEWISTOWN	MT
LWT-A	FSS	HD	LEWISTOWN	MT
LVM-R	FSS	HD	LIVINGSTON	MT
LVM-A	FSS	HD	LIVINGSTON	MT
MLS-R	FSS	HD	MILES CITY	MT
MLS-A	FSS	HD	MILES CITY	MT
MSO-R	FSS	HD	MISSOULA	MT
MSO-A	FSS	HD	MISSOULA	MT
EKO-R	FSS	HD	ELKO	NV
EKO-A	FSS	HD	ELKO	NV
ELY-R	FSS	HD	ELY	NV
ELY-A	FSS	HD	ELY	NV
TPH-R	FSS	HD	TONOPAH	NV
TPH-A	FSS	HD	TONOPAH	NV
BKE-R	FSS	HD	BAKER	OR
BKE-A	FSS	HD	BAKER	OR
ZLC-Z	ARTCC	FD	SALT LAKE CITY	UT
SCL-S	FSS	FD	SALT LAKE CITY	UT
SLC1A	ARTS	FD	SALT LAKE CITY	UT
SLC2A	ARTS	HD	SALT LAKE CITY	UT
ENV-A	AMOS	HD	WENDOVER	UT
RWL-R	FSS	HD	RAWLINS	WY
RWL-A	FSS	HD	RAWLINS	WY
RKS-R	FSS	HD	ROCK SPRINGS	WY
RKS-A	FSS	HD	ROCK SPRINGS	WY
SHR-R	FSS	HD	SHERIDAN	WY
SHR-A	FSS	HD	SHERIDAN	WY
WRL-A	FSS	HD	WORLAND	WY

SUMMARY [illegible] : 4
AREA A : 22
R/R : 16
CNTR : 1

ARTCC : ZMA

FMY-S	FSS	FD	FORT MYERS	FL
EYW-R	FSS	HD	KEY WEST	FL
EYW-A	FSS	HD	KEY WEST	FL
MCO-R	AFB	HD	MCCOY AFB	FL
MLB-S	FSS	FD	MELBOURNE	FL
MIA-S	FSS	FD	MIAMI	FL
ZMA-Z	ARTCC	FD	MIAMI	FL
OPF2A	TWR?LA	HD	MIAMI-OPA LOCKA	FL
OPF1A	TWR?LA	HD	MIAMI-OPA LOCKA	FL
ORL-S	FSS	FD	ORLANDO	FL
SPG-A	TWR?LA	HD	ST PETERSBURG-A	FL
PIE-S	FSS	FD	ST. PETERSBURG	FL
VRB-S	FSS	FD	VERO BEACH	FL
PBI-R	ARPT	HD	WEST PALM BEACH	FL
PBI-A	ARPT	HD	WEST PALM BEACH	FL

SUMMARY SHS : 6
AREA A : 5
R/S : 3
CNTR : 1

ARTCC : ZME

MSL-S	FSS	FD	MUSCLE SHOALS	AL
FYV-R	FSS	HD	FAYETTEVILLE	AR
FYV-A	FSS	RD	FAYETTEVILLE	AR
HRO-R	FSS	HD	HARRISON	AR
HRO-A	FSS	HD	HARRISON	AR
JBR-R	FSS	HD	JONESBORO	AR
JBR-A	FSS	HD	JONESBORO	AR
LIT-S	FSS	FD	LITTLE ROCK	AR
LRF-R	AFB/AW	HD	LITTLE ROCK AFB	AR
LRF2A	AFB/AW	RD	LITTLE ROCK AFB	AR
LRF1A	AFB?AW	RD	LITTLE ROCK AFB	AR
PBF-R	FSS	HD	PINE BLUFF	AR
PBF-A	FSS	HD	PINE BLUFF	AR
BWG-S	FSS	FD	BOWLING GREEN	KY
PAH-R	FSS	HD	PADUCAH	KY
PAH-A	FSS	HD	PADUCAH	KY
CGI-S	FSS	FD	CAPE GIRARDEAU	MO
GWO-S	FSS	FD	GREENWOOD	MS
JAN-S	FSS	FD	JACKSON	MS
MEI-R	FSS	HD	MERIDIAN	MS
MEI-A	FSS	HD	MERIDIAN	MS
DYR-R	FSS	HD	DYERSBURG	TN
DYR-A	FSS	HD	DYERSBURG	TN
MKL-R	FSS	HD	JACKSON	TN
MKL-A	FSS	HD	JACKSON	TN
ZME-Z	ARTCC	FD	MEMPHIS	TN
MEM-S	FSS	FD	MEMPHIS	TN
ZME-A	ARTCC	RD	MEMPHIS	TN
BNA-S	FSS	FD	NASHVILLE	TN

SUMMARY SAS : 8
AREA A : 11
R/R : 7
CNTR : 1

ARTCC : ZMP

DSM-S	FSS	FD	DES MOINES	IA
FOD-A	APT	HD	FORT DODGE	IA
MCW-S	FSS	FD	MASON CITY	IA
CMX-R	FSS	HD	HOUGHTON	MI
CMX-A	FSS	HD	HOUGHTON	MI
MQT-A	FSS	HD	MARQUETTE	MI
MQT-R	FSS	HD	MARQUETTE	MI
PLN-A	FSS	HD	PELLSTON	MI
PLN-R	FSS	HD	PELLSTON	MI
SSM-R	FSS	HD	SAULT STE MARIE	MI
SSM-A	FSS	HD	SAULT STE MARIE	MI
TVC-A	FSS	HD	TRAVERSE CITY	MI
TVC1R	FSS	HD	TRAVERSE CITY	MI
TVC2R	FSS	HD	TRAVERSE CITY	MI
AXN-S	FSS	FD	ALEXANDRIA	MN
HIB-S	FSS	FD	HIBBING	MN
ZMP-A	ARTCC	FD	MINNEAPOLIS	MN
MSP-S	FSS	FD	MINNEAPOLIS	MN
ZMP-Z	ARTCC	FD	MINNEAPOLIS	MN
RWF-S	FSS	FD	REDWOOD FALLS	MN
RST-R	FSS	HD	ROCHESTER	MN
RST-A	FSS	HD	ROCHESTER	MN
DVL-A	SAWRS	HD	DEVILS LAKE	ND
DIK-A	FSS	HD	DICKINSON	ND
DIK-R	FSS	HD	DICKINSON	ND
GFK-S	FSS	FD	GRAND FORKS	ND
JMS-R	FSS	HD	JAMESTOWN	ND
JMS-A	FSS	HD	JAMESTOWN	ND
MOT-A	FSS	HD	MINOT	ND
MOT-R	FSS	HD	MINOT	ND
P24-A	AMOS	HD	ROSEGLEN	ND
GRI-S	FSS	FD	GRAND ISLAND	NE
LNK-S	FSS	FD	LINCOLN	NE
OMA-S	FSS	FD	OMAHA	NE
ABR-A	FSS	HD	ABERDEEN	SD
ABR-R	FSS	HD	ABERDEEN	SD
HON-S	FSS	FD	HURON	SD
PIR-A	FSS	HD	PIERRE	SD
PIR-R	FSS	HD	PIERRE	SD
ATY-R	FSS	HD	WATERTOWN	SD
ATY-A	FSS	HD	WATERTOWN	SD
EAU-A	FSS	HD	EAU CLAIRE	WI
EAU1R	FSS	HD	EAU CLAIRE	WI
EAU2R	FSS	HD	EAU CLAIRE	WI
LSE-A	FSS	HD	LA CROSSE	WI
LSE-R	FSS	HD	LA CROSSE	WI

SUMMARY: LAS : [illegible]
AREA A : [illegible]
RCR : [illegible]
CNTR : [illegible]

ARTCC : ZNY

SBY-S	FSS	FD	SALISBURY	MD
MIV-S	FSS	FD	MILLVILLE	NJ
TEB-S	FSS	FD	TETERBORO	NJ
NOP-A	CGAS	RO	BROOKLYN CGAS	NY
ELM-S	FSS	FD	ELMIRA	NY
ISP-S	FSS	FD	ISLIP	NY
ISP-A	ATCT	RO	ISLIP	NY
LGA-A	ARPT	RO	LAGUARDIA	NY
RNY-A	COMCO	HD	NEW YORK	NY
JNY-R	ARTS	HD	NEW YORK	NY
ZNY-Z	ARTCC	FD	NEW YORK	NY
JNY-A	ARTS	RO	NEW YORK CIFRR	NY
POU-S	FSS	FD	POUGHKEEPSIE	NY
ART-R	ART	HD	WATERTOWN	NY
HPN-A	ANG	RO	WHITE PLAINS	NY
HAR-S	FSS	FD	HARRISBURG	PA
PNE-S	FSS	FD	PHILADELPHIA	PA
PSB-R	FSS	HD	PHILIPSBURG	PA
PSB-A	FSS	HD	PHILIPSBURG	PA
RDG-A	TRCAB	RO	READING	PA
AVP-S	FSS	FD	WILKES BARRE	PA
IPT-R	FSS	HD	WILLIAMSPORT	PA
IPT-A	FSS	HD	WILLIAMSPORT	PA

SUMMARY SAS : 9
AREA A : 9
R/R : 4
CNTR : 1

ARTCC : ZOA

ACV-R	FSS	HD	ARCATA	CA
ACV-A	FSS	HD	ARCATA	CA
EMT-A	TWR?LA	HD	EL MONTE	CA
FAT-S	FSS	FD	FRESNO	CA
FCH-A	TWR?LA	HD	FRESNO-CHANDLER	CA
MYV-R	FSS	HD	MARYSVILLE	CA
MYV1A	FSS	HD	MARYSVILLE	CA
MYV2A	FSS	RD	MARYSVILLE	CA
MHR-A	AFB?BA	HD	MATHER AFB	CA
OAK-S	FSS	FD	OAKLAND	CA
ZOA-Z	ARTCC	FD	OAKLAND	CA
OAK-A	ARTS	HD	OAKLAND	CA
PRB-S	FSS	FD	PASO ROBLES	CA
RBL-S	FSS	FD	RED BLUFF	CA
SAC-S	FSS	FD	SACRAMENTO	CA
SNS-S	FSS	FD	SALINAS	CA
SFO-S	ATCT	HD	SAN FRANCISCO	CA
SCK-S	FSS	FD	STOCKTON	CA
UKI-S	FSS	FD	UKIAH	CA
LOL-R	FSS	HD	LOVELOCK	NV
LOL-A	FSS	HD	LOVELOCK	NV
RNO-S	FSS	FD	RENO	NV

SUMMARY SAS : 9
AREA A : 8
R/R : 4
CNTR : 1

ARTCC : ZOB

ARB-A	TWR?LA	HD	ANN ARBOR	MI
DET-S	FSS	FD	DETROIT	MI
HLM-A	APT	HD	HOLLAND	MI
JXN-R	FSS	HD	JACKSON	MI
JXN-A	FSS	HD	JACKSON	MI
LAN-R	FSS	HD	LANSING	MI
LAN-A	FSS	HD	LANSING	MI
MBS-S	FSS	FD	SAGINAW	MI
BUF-S	FSS	FD	BUFFALO	NY
CAK-A	TRACO	HD	AKRON-CANTON	OH
CLE-S	FSS	FD	CLEVELAND	OH
ZOB-Z	ARTCC	FD	CLEVELAND	OH
ZOB-A	ARTCC	RD	CLEVELAND	OH
CGF-A	ARPT	RD	CLEVELAND-CYAGA	OH
BKL-A	ARPT	RD	CLEVELAND-LAKEF	OH
FDY-S	FSS	FD	FINDLAY	OH
MFD-A	ATCT	RD	MANSFIELD	OH
YNG-R	FSS	HD	YOUNGSTOWN	OH
YNG-A	FSS	HD	YOUNGSTOWN	OH
AOO-R	FSS	HD	ALTOONA	PA
AOO-A	FSS	HD	ALTOONA	PA
BFD-A	FSS	HD	BRADFORD	PA
BFD-R	FSS	HD	BRADFORD	PA
DUJ-A	FSS	HD	DUBOIS	PA
DUJ-R	FSS	HD	DUBOIS	PA
ERI-R	FSS	HD	ERIE	PA
ERI-A	FSS	HD	ERIE	PA
JST-R	FSS	HD	JOHNSTOWN	PA
JST-A	FSS	RD	JOHNSTOWN	PA
AGC-S	FSS	FD	PITTSBURGH	PA
CKB-A	TWR?LA	HD	CLARKSBURG	WV
MGW-R	FSS	HD	MORGANTOWN	WV
MGW-A	FSS	HD	MORGANTOWN	WV
HLG-A	CST	HD	WHEELING	WV

SUMMARY SAS : 6
AREA A : 19
R/R : 9
CNTR : 1

ARTCC : ZSE

CEC-A	FSS	RO	CRESCENT CITY	CA
CEC-R	FSS	HD	CRESENT CITY	CA
SIY-A	FSS	FD	MONTAGUE	CA
SIY-R	FSS	HD	MONTAGUE	CA
MHS-A	AMOS?W	HD	MOUNT SHASTA	CA
EUG-R	ATCT	HD	EUGENE	OR
OTH-S	FSS	FD	NORTH BEND	OR
PDX-S	FSS	FD	PORTLAND	OR
RDM-S	FSS	FD	REDMOND	OR
DLS-A	FSS	HD	THE DALLAS	OR
DLS-R	FSS	HD	THE DALLES	OR
BLI-S	FSS	FD	BELLINGHAM	WA
EPH-R	FSS	HD	EPHRATA	WA
EPH-A	FSS	HD	EPHRATA	WA
HQM-R	FSS	HD	HOQUIAM	WA
HQM-A	FSS	HD	HOQUIAM	WA
OLM-R	ARPT	HD	OLYMPIA	WA
ZSE-Z	ARTCC	FD	SEATTLE	WA
SEA-S	FSS	FD	SEATTLE	WA
BFI-A	LAWRS	HD	SEATTLE-BOEING	WA
SFF-S	FSS	FD	SPOKANE	WA
TDO-R	FSS	HD	TOLEDO	WA
TDO-A	FSS	RO	TOLEDO	WA
ALW-S	FSS	FD	WALLA WALLA	WA
EAT-S	FSS	FD	WENATCHEE	WA

SUMMARY SAS : 9
AREA A : 9
R/R : 8
CNTR : 1

ARTCC : ZSU

SJU-S FSS FD SAN JUAN RR

SUMMARY SAT : 1
AREA A : 0
R/R : 0
CNTR : 0

ARTCC : ZTL

ANB-S	FSS	FD	ANNISTON	AL
BHM-S	FSS	FD	BIRMINGHAM	AL
MGM-R	FSS	HD	MONTGOMERY	AL
MGM-A	FSS	HD	MONTGOMERY	AL
TCL-R	FSS	HD	TUSCALOOSA	AL
TCL-A	FSS	HD	TUSCALOOSA	AL
ZTL-A	ARTCC	SD	ATLANTA	GA
ZTL-Z	ARTCC	FD	ATLANTA	GA
ATL-R	FSS	HD	ATLANTA	GA
ATL-A	FSS	HD	ATLANTA	GA
FTY-R	ATCT	HD	FULTON COUNTY	GA
MCN-R	FSS	HD	MACON	GA
MCN-A	FSS	HD	MACON	GA
RMG-A	AMOS?W	HD	ROME	GA
AVL-R	ARPT	HD	ASHEVILLE	NC
HKY-S	FSS	FD	HICKORY	NC
42A-R	AFT	HD	HIGH POINT	NC
AND-R	FSS	HD	ANDERSON	SC
AND-A	FSS	HD	ANDERSON	SC
GMU-R	ARPT	HD	GREENVILLE	SC
GSP-S	FSS	FD	GREER	SC
CSV-S	FSS	FD	CROSSVILLE	TN
TYS-S	FSS	FD	KNOXVILLE	TN
TRI-S	FSS	HD	TRI CITY	TN
BLF-S	FSS	FD	BLUEFIEL	WV

SUMMARY SAS : 7
AREA B : 6
F/R : 9
CNTR : 1

APPENDIX D

NODAL LIST BY TYPE

D.1 This appendix presents nodes sorted by type, with vertical and horizontal grid coordinates, city, state, transmission mode (HD, FD, or RO), and center designated.

D.2 A small percentage of vertical and horizontal coordinates primarily in Alaska have not been determined.

D.3 This list provides a cross reference to Appendix C.

FAC	TR	LID	CITY	ST	VER	HOR	CTR
FSS	FD	ANC-S	ANCHORAGE	AK	3318	2528	ZAN
FSS	FD	BET-S	BETHEL	AK	0	0	ZAN
FSS	FD	FAI-S	FAIRBANKS	AK	2911	2411	ZAN
FSS	FD	ENA-S	KENAI	AK	0	0	ZAN
FSS	FD	ANB-S	ANNISTON	AL	7466	2384	ZTL
FSS	FD	BHM-S	BIRMINGHAM	AL	7519	2446	ZTL
FSS	FD	MOB-S	MOBILE	AL	7557	2367	ZHU
FSS	FD	MSL-S	MUSCLE SHOALS	AL	7254	2714	ZME
FSS	FD	LIT-S	LITTLE ROCK	AR	7721	3451	ZME
FSS	FD	PHX-S	PHOENIX	AZ	9135	6748	ZAB
FSS	FD	PRC-S	PRESCOTT	AZ	8917	6272	ZAB
FSS	FD	TUS-S	TUCSON	AZ	9345	6485	ZAB
FSS	FD	BFL-S	BAKERSFIELD	CA	8747	8060	ZLA
FSS	FD	FAT-S	FRESNO	CA	8669	8239	ZOA
FSS	FD	IPL-S	IMPERIAL	CA	9385	7348	ZLA
FSS	FD	WJF-S	LANCASTER	CA	9070	7852	ZLA
FSS	FD	LAX-S	LOS ANGELES	CA	9213	7692	ZLA
FSS	FD	OAK-S	OAKLAND	CA	8486	8695	ZOA
FSS	FD	ONT-S	ONTARIO	CA	9175	7771	ZLA
FSS	FD	PRB-S	PASO ROBLES	CA	8930	8465	ZOA
FSS	FD	RBL-S	RED BLUFF	CA	7917	8745	ZOA
FSS	FD	SAC-S	SACRAMENTO	CA	8304	8580	ZOA
FSS	FD	SNS-S	SALINAS	CA	8722	8560	ZOA
FSS	FD	SAN-S	SAN DIEGO	CA	9418	7629	ZLA
FSS	FD	SBA-S	SANTA BARBARA	CA	9171	8150	ZLA
FSS	FD	SCK-S	STOCKTON	CA	8435	8530	ZOA
FSS	FD	TRM-S	THERMAL	CA	9223	7501	ZLA
FSS	FD	UKI-S	UKIAH	CA	8206	8885	ZOA
FSS	FD	DEN-S	DENVER	CO	7501	5899	[illegible]
FSS	FD	GJT-S	GRAND JUNCTION	CO	7804	6438	[illegible]
FSS	FD	BDL-S	WINDSOR LOCKS	CT	4654	1385	ZBW
FSS	FD	FMY-S	FORT MYERS	FL	8359	904	ZMA
FSS	FD	GNV-S	GAINESVILLE	FL	7838	1310	[illegible]
FSS	FD	JAX-S	JACKSONVILLE	FL	9649	1276	[illegible]
FSS	FD	MLB-S	MELBORNE	FL	7963	854	ZMA
FSS	FD	MIA-S	MIAMI	FL	8400	535	ZMA
FSS	FD	ORL-S	ORLANDO	FL	7754	1011	ZMA
FSS	FD	PIE-S	ST. PETERSBURG	FL	8202	1206	ZMA
FSS	FD	TLH-S	TALLAHASSEE	FL	7877	1716	[illegible]
FSS	FD	VRB-S	VERO BEACH	FL	8124	770	ZMA
FSS	FD	SAV-S	SAVANNAH	GA	7165	1377	[illegible]
FSS	FD	HNL-S	HONOLULU	HI	0	0	[illegible]
FSS	FD	BRL-S	BURLINGTON	IA	6449	3511	ZAU
FSS	FD	CID-S	CEDAR RAPIDS	IA	1261	4021	[illegible]
FSS	FD	DSM-S	DES MOINES	IA	6471	4275	[illegible]

LEASED SERVICE A NODES: TOTAL 149

FAC	TR	LID	CITY	ST	VER	HOR	CTR
FSS	FD	MCW-S	MASON CITY	IA	6136	4352	ZMP
FSS	FD	BOI-S	BOISE	ID	7096	[illegible]	[illegible]
FSS	FD	BYI-S	BURLEY	ID	7246	7449	ZLC
FSS	FD	CHI-S	CHICAGO	IL	6037	[illegible]	ZAU
FSS	FD	DEC-S	DECATUR	IL	6479	3413	[illegible]
FSS	FD	UIN-S	QUINCY	IL	6627	3764	[illegible]
FSS	FD	RFD-S	ROCKFORD	IL	6022	3675	ZAU
FSS	FD	FWA-S	FORT WAYNE	IN	5942	2952	ZAU
FSS	FD	LAF-S	LAFAYETTE	IN	6206	3167	ZID
FSS	FD	SBN-S	SOUTH BEND	IN	5918	3206	ZAU
FSS	FD	HUF-S	TERRE HAUTE	IN	6429	[illegible]	ZID
FSS	FD	CNU-S	CHANUTE	KS	7368	[illegible]	ZKC
FSS	FD	GCK-S	GARDEN CITY	KS	7646	5113	ZKC
FSS	FD	ICT-S	WICHITA	KS	7489	4520	ZKC
FSS	FD	BWG-S	BOWLING GREEN	KY	6822	2745	ZME
FSS	FD	LOZ-S	LONDON	KY	6596	2401	ZID
FSS	FD	LOU-S	LOUISVILLE	KY	6525	2772	ZID
FSS	FD	NEW-S	NEW ORLEANS	LA	8453	2638	ZHU
FSS	FD	SHV-S	SHREVEPORT	LA	8272	3495	ZFW
FSS	FD	BOS-S	BOSTON	MA	4417	1249	ZBW
FSS	FD	SBY-S	SALISBURY	MD	5578	1315	ZNY
FSS	FD	AUG-S	AUGUSTA	ME	3661	1370	ZBW
FSS	FD	DET-S	DETROIT	MI	5536	2828	ZOB
FSS	FD	MBS-S	SAGINAW	MI	5401	3108	ZOB
FSS	FD	AXN-S	ALEXANDRIA	MN	5730	[illegible]	ZMP
FSS	FD	HIB-S	HIBBING	MN	5276	4701	ZMP
FSS	FD	MSP-S	MINNEAPOLIS	MN	5781	4525	ZMP
FSS	FD	RWF-S	REDWOOD FALLS	MN	5982	4750	ZMP
FSS	FD	CGI-S	CAPE GIRARDEAU	MO	7013	3251	ZME
FSS	FD	COU-S	COLUMBIA	MO	[illegible]	3841	ZKC
FSS	FD	MKC-S	KANSAS CITY	MO	7027	4203	ZKC
FSS	FD	SGF-S	SPRINGFIELD	MO	7310	3936	ZKC
FSS	FD	STL-S	ST. LOUIS	MO	6834	3545	ZKC
FSS	FD	GWO-S	GREENWOOD	MS	7798	[illegible]	ZME
FSS	FD	JAN-S	JACKSON	MS	9035	[illegible]	ZME
FSS	FD	GTF-S	GREAT FALLS	MT	6120	7231	ZLC
FSS	FD	HKY-S	HICKORY	NC	6511	[illegible]	ZTL
FSS	FD	EWN-S	NEW BERN	NC	6307	1115	ZDC
FSS	FD	RDU-S	RALEIGH-DURHAM	NC	6344	1436	ZDC
FSS	FD	GFK-S	GRAND FORKS	ND	5420	5300	ZMP
FSS	FD	GRI-S	GRAND ISLAND	NE	6901	4936	ZMP
FSS	FD	LNK-S	LINCOLN	NE	6823	[illegible]	ZMP
FSS	FD	LBF-S	NORTH PLATTE	NE	6995	5325	ZDV
FSS	FD	OMA-S	OMAHA	NE	6687	4595	ZMP
FSS	FD	CON-S	CONCORD	NH	4326	1426	ZBW

LEASED SERVICE A NODES: TOTAL 149 (Continued)

FAC	TR	LID	CITY	ST	VER	HOR	CTR
FSS	FD	MIV-S	MILLVILLE	NJ	5338	1371	ZNY
FSS	FD	TEB-S	TETERBORO	NJ	4984	1434	ZNY
FSS	FD	ABQ-S	ALBUQUERQUE	NM	8549	5887	ZAB
FSS	FD	LAS-S	LAS VEGAS	NV	8665	7411	ZLA
FSS	FD	RNO-S	RENO	NV	8064	9323	[illegible]
FSS	FD	ALB-S	ALBANY	NY	4629	1649	ZBW
FSS	FD	BUF-S	BUFFALO	NY	5050	2320	ZOB
FSS	FD	ELM-S	ELMIRA	NY	5029	1953	ZNY
FSS	FD	ISP-S	ISLIP	NY	[illegible]	1406	ZNY
FSS	FD	POU-S	POUGHKEEPSIE	NY	4821	1526	ZNY
FSS	FD	UCA-S	UTICA	NY	4743	1932	ZBW
FSS	FD	LUK-S	CINCINNATI	OH	[illegible]	2679	ZID
FSS	FD	CLE-S	CLEVELAND	OH	5574	2543	ZOB
FSS	FD	CMH-S	COLUMBUS	OH	5972	2555	ZID
FSS	FD	DAY-S	DAYTON	OH	6088	2719	ZID
FSS	FD	FDY-S	FINDLAY	OH	5828	2766	ZOB
FSS	FD	OKC-S	OKLAHOMA CITY	OK	7946	4394	ZFW
FSS	FD	TUL-S	TULSA	OK	7707	4171	ZFW
FSS	FD	OTH-S	NORTH BEND	OR	7293	9122	ZSE
FSS	FD	PDX-S	PORTLAND	OR	[illegible]	[illegible]	ZSE
FSS	FD	RDM-S	REDMOND	OR	[illegible]	8660	ZSE
FSS	FD	HAR-S	HARRISBURG	PA	5363	1733	ZNY
FSS	FD	PNE-S	PHILADELPHIA	PA	5219	1458	ZNY
FSS	FD	AGC-S	PITTSBURGH	PA	5621	2185	ZOB
FSS	FD	AVP-S	WILKES BARRE	PA	5059	1717	ZNY
FSS	FD	SJU-S	SAN JUAN	PR	0	0	ZSU
FSS	FD	CHS-S	CHARLESTON	SC	7021	1231	ZJX
FSS	FD	FLO-S	FLORENCE	SC	6744	1417	ZJX
FSS	FD	GSP-S	GREER	SC	6939	1977	ZTL
FSS	FD	HON-S	HURON	SD	6201	5183	ZMP
FSS	FD	CSV-S	CROSSVILLE	TN	[illegible]	2419	ZTL
FSS	FD	TYS-S	KNOXVILLE	TN	6844	2234	ZT
FSS	FD	MEM-S	MEMPHIS	TN	7471	3125	ZME
FSS	FD	BNA-S	NASHVILLE	TN	7010	2710	ZME
FSS	FD	AMA-S	AMARILLO	TX	8266	5076	ZAB
FSS	FD	AUS-S	AUSTIN	TX	9005	3996	ZHU
FSS	FD	DAL-S	DALLAS	TX	8436	4034	ZFW
FSS	FD	ELP-S	EL PASO	TX	9231	5655	ZAB
FSS	FD	FTW-S	FORT WORTH	TX	8479	4122	ZFW
FSS	FD	HOU-S	HOUSTON	TX	8938	3536	ZHU
FSS	FD	MAF-S	MIDLAND	TX	8934	4286	ZFW
FSS	FD	SAT-S	SAN ANTONIO	TX	9225	4062	ZHU
FSS	FD	SCL-S	SALT LAKE CITY	UT	7576	7065	ZLC
FSS	FD	PHF-S	NEWPORT NEWS	VA	5888	1251	ZDC
FSS	FD	ROA-S	ROANOKE	VA	6196	[illegible]	ZDC

LEASED SERVICE A NODES: TOTAL 149 (Continued)

FAC	TR	LID	CTY	ST	VER	HOR	CTR
FSS	FD	MPV-S	MONTPELIER	VT	4246	1701	ZBW
FSS	FD	BLI-S	BELLINGHAM	WA	6087	8933	ZSE
FSS	FD	SEA-S	SEATTLE	WA	6336	8894	ZSE
FSS	FD	SFF-S	SPOKANE	WA	6247	8180	ZSE
FSS	FD	ALW-S	WALLA WALLA	WA	6611	8219	ZSE
FSS	FD	EAT-S	WENATCHEE	WA	6349	8596	ZSE
FSS	FD	GRB-S	GREENBAY	WI	5512	3747	ZAU
FSS	FD	MKE-S	MILWAUKEE	WI	5788	3589	ZAU
FSS	FD	AUW-S	WAUSAU	WI	5542	4014	ZAU
FSS	FD	BLF-S	BLUEFIEL	WV	3316	1591	ZTL
FSS	FD	CRW-S	CHARLESTON	WV	6152	2174	ZID
FSS	FD	MRB-S	MARTINSBURG	WV	5611	1793	ZDC
FSS	FD	PKB-S	PARKERSBURG	WV	5976	2246	ZID
FSS	FD	CPR-S	CASPER	WY	6919	6297	ZDV

LEASED SERVICE A NODES: TOTAL 149 (Concluded)

FAC	TR	LID	CITY	ST	VER	HOR	CTR
FSS	HD	ADK-A	ADAK	AK	736	6413	ZAN
ARTS	RO	ANC-A	ANCHORAGE	AK	2018	2828	ZAN
FSS	HD	ANI-A	ANIAK	AK	2169	3932	ZAN
RCO	HD	ANN-A	ANNETTE ISLAND	AK	0	0	ZAN
RCO	HD	OAM-A	ANVIL MOUNTAIN	AK	0	0	ZAN
FSS	HD	BRW1A	BARROW	AK	0	0	ZAN
FSS	RO	BRW2A	BARROW	AK	0	0	ZAN
FSS	HD	CDV-A	CORDOVA	AK	0	0	ZAN
FSS	HD	SCC-A	DEADHORSE	AK	3956	2383	ZAN
ARTS	HD	FAI-A	FAIRBANKS	AK	0		ZAN
FSS	HD	HOM1A	HOMER	AK	0	0	ZAN
FSS	RO	HOM2A	HOMER	AK	0	0	ZAN
FSS	HD	JNU1A	JUNEAU	AK	1598	1056	ZAN
FSS	RO	JNU2A	JUNEAU	AK	1597	1055	ZAN
FSS	HD	KTN1A	KETCHIKAN	AK	0	0	ZAN
FSS	RO	KTN2A	KETCHIKAN	AK	0	0	ZAN
FSS	RO	KTN3A	KETCHIKAN	AK	0	0	ZAN
FSS	HD	ADQ-A	KODIAK	AK	0	0	ZAN
FSS	HD	OTZ-A	KOTZEBUE	AK	3135	3515	ZAN
FSS	HD	MCG-A	MCGRATH	AK	2419	3357	ZAN
RCO	HD	MDO-A	MIDDLETON ISLAND	AK	1111	541	ZAN
FSS	HD	OME1A	NOME	AK	0	0	ZAN
FSS	RO	OME2A	NOME	AK	0	0	ZAN
FSS	RO	OME3A	NOME	AK	0	0	ZAN
FSS	HD	ORT1A	NORTHWAY	AK	2451	2030	ZAN
FSS	RO	ORT2A	NORTHWAY	AK	2451	2030	ZAN
FSS	HD	PAQ-A	PALMER	AK	0	0	ZAN
FSS	HD	SIT1A	SITKA	AK	0	0	ZAN
FSS	RO	SIT2A	SITKA	AK	0	0	ZAN
FSS	RO	SIT3A	SITKA	AK	0	0	ZAN
CST	HD	VDZ-A	VALDEZ	AK	0	0	ZAN
FSS	HD	YAK1A	YAKUTAT	AK	0	0	ZAN
FSS	RO	YAK2A	YAKUTAT	AK	0	0	ZAN
FSS	RO	YAK3A	YAKUTAT	AK	0	0	ZAN
FSS	HD	DHN-A	DOTHAN	AL	7930	1990	ZJX
FSS	HD	MGM-A	MONTGOMERY	AL	7692	2247	ZTL
FSS	HD	TCL-A	TUSCALOOSA	AL	7642	2535	ZTL
FSS	HD	ELD-A	EL DORADO	AR	9051	3376	ZFW
FSS	RO	FYV-A	FAYETTEVILLE	AR	7600	3072	ZME
FSS	HD	HRO-A	HARRISON	AR	7490	3718	ZME
FSS	HD	JBR-A	JONESBORO	AR	7389	3297	ZME
AFB?AW	RO	LRF1A	LITTLE ROCK AFB	AR	7695	3433	ZME
AFB/AW	RO	LRF2A	LITTLE ROCK AFB	AR	7695	3433	ZME
FSS	HD	PBF-A	PINE BLUFF	AR	7803	1358	ZME
FSS	HD	DUG-A	DOUGLAS	AZ	9466	6192	ZAB

AREA A NODES: TOTAL 294

FAC	TR	LID	CITY	ST	VER	HOR	[illegible]
AMOS	HD	IGM-A	KINGMAN	AZ	8837	7179	ZLA
AAF	HD	FHU-A	LIBBY AAF	AZ	9457	6331	ZAB
AMOS?B	RO	PGA-A	PAGE	AZ	[illegible]	6819	ZAB
FSS	HD	YUM-A	YUMA	AZ	9385	7171	ZLA
FSS	HD	ACV-A	ARCATA	CA	7841	9063	ZOA
FSS	HD	BLH-A	BLYHE	CA	9194	7206	ZLA
APT	RO	CXL-A	CALEXICO	CA	9426	7328	ZLA
FSS	RO	CEC-A	CRESCENT CITY	CA	7645	9096	ZSE
FSS	HD	DAG-A	DAGGETT	CA	8995	7691	ZLA
TWR?LA	RO	EMT-A	EL MONTE	CA	9202	7840	ZOA
TWR?LA	HD	FCH-A	FRESNO-CHANDLER	CA	8669	8239	ZLA
TWR?LA	HD	FCH-A	FRESNO-CHANDLER	CA	8669	8239	ZOA
FSS	HD	FUL-A	FULLERTON	CA	9244	7813	ZLA
ARTS	RO	LAX-A	LOS ANGELES	CA	9236	7891	ZLA
COMCO	HD	RLA-A	LOS ANGELES	CA	9245	7891	ZLA
ARTCC	RO	ZLA-A	LOS ANGELES	CA	9094	7873	ZLA
ARTCC	RO	ZLA-A	LOS ANGELES	CA	9094	7873	ZLA
AFB?AW	RO	RIV-A	MARCH AFB	CA	9214	7697	ZLA
FSS	HD	MYV1A	MARYSVILLE	CA	8182	8612	ZOA
FSS	RO	MYV2A	MARYSVILLE	CA	8182	8612	ZOA
AFB?BA	HD	MHR-A	MATHER AFB	CA	8304	8580	ZOA
FSS	RO	SIY-A	MONTAGUE	CA	7631	8823	ZSE
AMOS?W	HD	MHS-A	MOUNT SHASTA	CA	7718	8781	ZSE
FSS	RO	EED-A	NEEDLES	CA	8903	7263	ZLA
AFB	RO	SBD-A	NORTON AFB	CA	9172	7710	ZLA
ARTS	HD	OAK-A	OAKLAND	CA	8486	8695	ZOA
TWR?LA	RO	PMD-A	PALMDALE	CA	9094	7873	ZLA
TWR?LA	RO	PMD-A	PALMDALE	CA	9094	7873	ZLA
TWR?LA	RO	RAL-A	RIVERSIDE	CA	9202	7717	ZLA
ATCT	RO	SAN-A	SAN DIEGO	CA	9468	7629	ZLA
FSS	RO	SNA1A	SANTA ANA	CA	9267	7798	ZLA
FSS	RO	SNA2A	SANTA ANA	CA	9267	7798	ZLA
FSS	HD	AKO-A	AKRON	CO	[illegible]	5642	ZDV
COMCO	RO	RDE-A	AURORA	CO	7474	5980	ZDV
ARTCC	RO	ZDV-A	DENVER	CO	7419	5943	ZDV
FSS	HD	EGE-A	EAGLE	CO	7606	6190	ZDV
TWR?LA	RO	BJC-A	JEFFCO	CO	7494	5880	ZDV
FSS	HD	LHX-A	LA JUNTA	CO	7755	5501	ZDV
TRCAB	HD	PUB-A	PUEBLO	CO	7737	5742	ZDV
FSS	HD	TAD-A	TRINIDAD	CO	8008	5656	ZDV
ARTS	RO	DCA1A	WASHINGTON	DC	5632	1590	ZDC
ARTS	RO	DCA2A	WASHINGTON	DC	5632	1590	ZDC
COMCO	HD	RWA-A	WASHINGTON	DC	5622	1583	ZDC
ARTCC	RO	ZDC-A	WASHINGTON	DC	5634	1635	ZDC
FSS	HD	CEW-A	CRESTVIEW	FL	8025	2128	ZJX

AREA A NODES: TOTAL 294 (Continued)

FAC	TR	LID	CITY	ST	VER	HOR	CTR
APT	HD	CTY-A	CROSS CITY	FL	7920	1479	ZJX
FSS	HD	EYW-A	KEY WEST	FL	8745	669	ZMA
TWR?LA	HD	OPF1A	MIAMI-OPA LOCKA	FL	8351	527	ZMA
TWR?LA	RO	OPF2A	MIAMI-OPA LOCKA	FL	8351	527	ZMA
FSS	HD	PNS-A	PENSACOLA	FL	8147	2200	ZJX
TWR?LA	HD	SPG-A	ST PETERSBURG-A	FL	8224	1159	ZMA
ARPT	HD	PBI-A	WEST PALM BEACH	FL	8166	607	ZMA
FSS	HD	ABY-A	ALBANY	GA	7649	1317	ZJX
FSS	HD	AMG-A	ALMA	GA	7498	1539	ZJX
FSS	HD	ATL-A	ATLANTA	GA	7260	2083	ZTL
ARTCC	RO	ZTL-A	ATLANTA	GA	7320	2029	ZTL
FSS	HD	SSI-A	BRUNSWICK	GA	7469	1320	ZJX
FSS	HD	MCN-A	MACON	GA	7364	1865	ZTL
AMOS?W	HD	RMG-A	ROME	GA	7234	2262	ZTL
FSS	HD	VLD-A	VALDOSTA	GA	7709	1594	ZJX
APT	HD	FOD-A	FORT DODGE	IA	6328	4438	ZMP
FSS	HD	OTM-A	OTTUMWA	IA	6500	4042	ZAU
FSS	HD	IDA-A	IDAHO FALLS	ID	6996	7214	ZLC
ARTCC	RO	ZAU-A	CHICAGO	IL	6062	3511	ZAU
COMCO	HD	RGC-A	DES PLAINES	IL	5976	3479	ZAU
ARPT	HD	PIA-A	PEORIA	IL	7027	4203	ZAU
FSS	HD	IND-A	INDIANAPOLIS	IN	6272	2992	ZID
ARTCC	RO	ZID-A	INDIANAPOLIS	IN	6272	2992	ZID
FSS	HD	DDC-A	DODGE CITY	KS	7640	4958	ZKC
FSS	HD	EMP-A	EMPORIA	KS	7273	4394	ZKC
FSS	HD	GLD-A	GOODLAND	KS	7414	5345	ZDV
FSS	HD	HLC-A	HILL CITY	KS	7304	5051	ZDV
ARTCC	RO	ZKC-A	KANSAS CITY	KS	7088	4220	ZKC
ARTCC	RO	ZKC-A	KANSAS CITY	KS	7088	4220	ZKC
FSS	HD	MHK-A	MANHATTAN	KS	7143	4520	ZKC
FSS	HD	RSL-A	RUSSELL	KS	7342	4858	ZKC
FSS	HD	SLN-A	SALINA	KS	7275	4656	ZKC
FSS	HD	PAH-A	PADUCAH	KY	6982	3088	ZME
FSS	HD	ESF-A	ESLER FIELD	LA	8409	3118	ZHU
FSS	HD	LFT-A	LAFAYETTE	LA	8557	3169	ZHU
FSS	HD	LCH-A	LAKE CHARLES	LA	8675	3202	ZHU
FSS	HD	MLU-A	MONROE	LA	8148	3218	ZFW
TRW?LA	HD	NEW-A	NEW ORLEANS-LAK	LA	8483	[illegible]	ZHU
TWR?LA	HD	BED-A	BEDFORD	MA	4424	1291	ZBW
ARPT	RO	BED-A	BEDFORD	MA	4424	1283	ZBW
COMCO	RO	RBN-A	BURLINGTON	MA	4411	1286	ZBW
ATCT	RO	ACK-A	NANTUCKET	MA	[illegible]	[illegible]	ZBW
CGAS	RO	FMH-A	OTIS AFB	MA	4494	1094	ZBW
APT	RO	PSF-A	PITTSFIELD	MA	4626	1039	ZBW
AMOS?W	RO	ORH1A	WORCESTER	MA	4512	[illegible]	ZBW

AREA A NODES: TOTAL 294 (Continued)

FAC	TR	LID	CITY	ST	VER	HOR	CTR
ATCT	RO	ORH2A	WORCESTER	MA	4513	[illegible]	ZBW
FSS	HD	BGR-A	BANGOR	ME	3777	1322	ZBW
AMOS	HD	6B2-A	GREENVILLE	ME	3752	1515	ZBW
FSS	HD	HUL-A	HOULTON	ME	3465	1412	ZBW
AID	RO	OLD-A	OLD TOWN	ME	3743	1327	ZBW
TWR?LA	HD	ARB-A	ANN ARBOR	MI	5602	2918	ZOB
TWR?LA	RO	BTL-A	BATTLE CREEK	MI	5713	3124	ZAU
ATCT	RO	BTL-A	BATTLE CREEK	MI	5713	3124	[illegible]
APT	HD	HLM-A	HOLLAND	MI	5695	3303	ZOB
FSS	HD	CMX-A	HOUGHTON	MI	5052	4038	ZMP
FSS	HD	JXN-A	JACKSON	MI	5663	3009	ZOB
FSS	HD	LAN-A	LANSING	MI	5584	3081	ZOB
FSS	HD	MQT-A	MARQUETTE	MI	5079	3373	ZMP
FSS	HD	PLN-A	PELLSTON	MI	5074	3422	ZMP
FSS	HD	SSM-A	SAULT STE MARIE	MI	4863	3471	ZMP
FSS	HD	TVC-A	TRAVERSE CITY	MI	5294	3447	[illegible]
ARTCC	RO	ZMP-A	MINNEAPOLIS	MN	5838	4477	ZMP
FSS	HD	RST-A	ROCHESTER	MN	5916	4326	ZMP
FSS	HD	JLN-A	JOPLIN	MO	7421	4015	ZKC
FSS	HD	VIH-A	VICHY	MO	7024	3675	ZKC
FSS	HD	MCB-A	MCCOMB	MS	[illegible]	2823	ZHU
FSS	HD	MEI-A	MERIDIAN	MS	[illegible]	2639	ZME
FSS	HD	BIL-A	BILLINGS	MT	6391	6790	ZLC
FSS	RO	BIL-A	BILLINGS	MT	6391	6790	ZLC
FSS	HD	BZN-A	BOZEMAN	MT	6485	7186	ZLC
FSS	HD	BTM-A	BUTTE	MT	6480	7395	ZLC
FSS	HD	CTB-A	CUT BANK	MT	5911	7475	ZLC
ATCT	HD	GTF-A	GREAT FALLS	MT	6129	7281	ZLC
FSS	HD	LWT-A	LEWISTOWN	MT	6152	6990	ZLC
FSS	HD	LVM-A	LIVINGSTON	MT	6488	7089	ZLC
FSS	HD	MLS-A	MILES CITY	MT	6155	6433	ZLC
FSS	HD	MSO-A	MISSOULA	MT	63336	7650	ZLC
FSS	HD	ECG-A	ELIZABETH	NC	6010	1144	ZDC
APT	HD	W72-A	HATTERAS	NC	6127	915	ZDC
FSS	HD	RWI-A	ROCKY MOUNT	NC	6232	1329	ZDC
ARPT	RO	ILM-A	WILMINGTON	NC	6559	1143	ZJX
SAWRS	HD	DVL-A	DEVILS LAKE	ND	5478	5564	ZMP
FSS	HD	DIK-A	DICKINSON	ND	5922	6024	ZMP
FSS	HD	JMS-A	JAMESTOWN	ND	5713	5450	ZMP
FSS	HD	MOT-A	MINOT	ND	5573	5909	ZMP
AMOS	HD	P24-A	ROSEGLEN	ND	5696	5950	ZMP
FSS	HD	CDR-A	CHADRON	NE	6767	5786	ZDV
FSS	HD	BFF-A	SCOTTSBLUFF	NE	[illegible]	5625	ZDV
FSS	HD	SNY-A	SIDNEY	NE	7111	5671	ZDV
ARTCC	RO	ZBW-A	BOSTON	NH	4394	1356	ZBW

<u>AREA A NODES: TOTAL 294</u> (Continued)

FAC	TR	LID	CITY	ST	VER	HOR	[illegible]
APT	RO	LCI-A	LACONIA	NH	4263	1415	ZBW
FSS	HD	LEB-A	LEBANON	NH	4326	1584	ZBW
FSS	HD	CNM-A	CARLSBAD	NM	9974	5299	ZAB
AMOS?W	HD	CA01A	CLAYTON	NM	8097	5387	ZAB
AMOS?W	RO	CA02A	CLAYTON	NM	8097	5387	ZAB
APT	HD	CA03A	CLAYTON	NM	8087	5387	ZAB
FSS	HD	DMN-A	DEMING	NM	9199	5914	ZAB
FSS	HD	GUP-A	GALLUP	NM	8555	6273	ZAB
APT	HD	GNT-A	GRANTS	NM	8591	6099	ZAB
FSS	HD	LVS-A	LAS VEGAS	NM	8370	5676	ZAB
FSS	HD	ROW-A	ROSWELL	NM	8787	5413	ZAB
ATCT	RO	SAF-A	SANTE FE	NM	8334	5804	ZAB
FSS	HD	TCS-A	TRUTH OR CONSEQ	NM	8984	5875	ZAB
FSS	HD	TCC-A	TUCUMCARI	NM	8378	5393	ZAB
FSS	HD	EKO-A	ELKO	NV	7692	7698	ZLC
FSS	HD	ELY-A	ELY	NV	7917	7492	ZLC
FSS	HD	LOL-A	LOVELOCK	NV	7892	8121	ZOA
FSS	HD	TPH-A	TONOPAH	NV	8319	7843	ZLC
CGAS	RO	NGP-A	BROOKLYN CGAS	NY	4997	1405	ZNY
FSS	HD	GFL-A	GLEN FALLS	NY	4514	1704	ZBW
ATCT	RO	ISP-A	ISLIP	NY	4894	1301	ZNY
ARPT	RO	LGA-A	LAGUARDIA	NY	4997	1406	ZNY
FSS	HD	MSS-A	MASSENA	NY	4349	2075	ZBW
COMCO	HD	RNY-A	NEW YORK	NY	4997	1406	ZNY
ARTS	RO	JNY-A	NEW YORK CIFRR	NY	4997	1406	ZNY
FSS	HD	ART-A	WATERTOWN	NY	4618	[illegible]	ZBW
ANG	RO	HPN-A	WHITE PLAINS	NY	4921	1413	ZNY
TRACO	HD	CAK-A	AKRON-CANTON	OH	5665	2431	ZOB
ARTCC	RO	ZOB-A	CLEVELAND	OH	5659	2594	ZOB
ARPT	RO	CGF-A	CLEVELAND-CYHGA	OH	5548	2392	ZOB
ARPT	RO	BKL-A	CLEVELAND-LAKEF	OH	5574	2543	ZOB
LAWRS	RO	OSU-A	COLUMBUS	OH	5972	2555	ZID
ATCT	RO	MFD-A	MANSFIELD	OH	5793	2575	ZOB
FSS	HD	YNG-A	YOUNGSTOWN	OH	5549	2392	ZOB
FSS	HD	ZZV-A	ZANESVILLE	OH	5990	2410	ZID
FSS	HD	GAG-A	GAGE	OK	7917	4908	ZKC
FSS	HD	HBR-A	HOBART	OK	8169	4643	ZFW
FSS	HD	MLC-A	MCALESTER	OK	7936	4039	ZFW
ATCT	RO	OKC-A	OKLAHOMA CITY	OK	7947	4373	ZFW
FSS	HD	PNC-A	PONCA CITY	OK	7471	4407	ZKC
LAWRS	HD	RVS-A	TULSA-RIVERSIDE	OK	7707	4173	ZFW
FSS	HD	BKE-A	BAKER	OR	6880	8153	ZLC
FSS	HD	DLS-A	THE DALLAS	OR	6762	8639	ZSE
FSS	HD	AOO-A	ALTOONA	PA	5491	1937	ZOB
FSS	HD	BFD-A	BRADFORD	PA	5221	2182	ZOB

AREA A NODES: TOTAL 294 (Continued)

FAC	TP	LID	CITY	ST	VER	HOR	CTR
FSS	HD	DUJ-A	DUBOIS	PA	5337	2137	ZOB
FSS	HD	ERI-A	ERIE	PA	5321	2397	ZOB
FSS	RO	JST-A	JOHNSTOWN	PA	5542	2021	[illegible]
FSS	HD	PSB-A	PHILIPSBURG	PA	5375	1995	ZNY
TRCAB	RO	RDG-A	READING	PA	5252	1612	ZNY
FSS	HD	IPT-A	WILLIAMSPORT	PA	5200	1973	ZNY
ATCT	RO	PVD-A	PROVIDENCE	RI	4570	1203	ZBW
FSS	HD	AND-A	ANDERSON	SC	6961	1994	ZTL
FSS	HD	CRE-A	NORTH MYRTLE BE	SC	6750	1223	ZJX
FSS	HD	ABR-A	ABERDEEN	SD	5992	5303	ZMP
AMOS	HD	CHB-A	CHAMBERLAIN	SD	6374	5305	ZDV
FSS	HD	PIR-A	PIERRE	SD	6316	5497	ZMP
FSS	HD	RAP-A	RAPID CITY	SD	6518	5903	ZDV
FSS	HD	ATY-A	WATERTOWN	SD	6029	5065	ZMP
FSS	HD	DYR-A	DYERSBURG	TN	7245	3107	ZME
FSS	HD	MKL-A	JACKSON	TN	7282	2976	ZME
ARTCC	RO	ZME-A	MEMPHIS	TN	7471	3125	ZME
FSS	HD	TRI-S	TRI CITY	TN	6552	2070	ZTL
FSS	HD	ABI-A	ABILENE	TX	8698	4513	ZFW
FSS	HD	ALI-A	ALICE	TX	[illegible]	3855	ZHU
ARPT	HD	BPT-A	BEAUMONT	TX	8789	3316	ZHU
ATCT	HD	BRO-A	BROWNSVILLE	TX	9861	3601	ZHU
FSS	HD	CDS-A	CHILDRESS	TX	8323	4743	ZFW
FSS	HD	CLL-A	COLLEGE STATION	TX	8827	3788	ZHU
FSS	HD	COT-A	COTULLA	TX	9476	4120	ZHU
FSS	HD	DHT-A	DALHART	TX	8129	5249	ZAB
APT	HD	DRT-A	DEL RIO	TX	9399	4490	ZHU
ARTCC	RO	ZFW-A	FORT WORTH	TX	8447	4092	ZFW
AMOS?F	RO	GLS-A	GALVESTON	TX	8985	3397	ZHU
FSS	HD	GLS2A	GALVESTON	TX	8985	3397	ZHU
ARTCC	RO	ZHU-A	HOUSTON	TX	8892	3556	ZHU
TRCAB	HD	HOU-A	HOUSTON-HOBBY	TX	8938	3536	ZHU
FSS	HD	LBB-A	LUBBOCK	TX	8598	4962	ZFW
FSS	HD	LFK-A	LUFKIN	TX	8575	3561	ZHU
AMOS?B	HD	MRF-A	MARFA	TX	9394	5152	ZAB
FSS	HD	MFE-A	MCALLEN	TX	9859	3764	ZHU
FSS	HD	MWL-A	MINERAL WELLS	TX	8520	4261	ZFW
FSS	HD	PSX-A	PALACIOS	TX	9208	3600	ZHU
LAWRS	HD	SSF-A	SAN ANTONIO-STI	TX	9225	4062	ZHU
LAWRS	HD	SSF-A	SAN ANTONIO-STI	TX	9225	4062	ZHU
FSS	HD	SPS-A	WICHITA FALLS	TX	8326	4410	ZFW
FSS	HD	INK-A	WINK	TX	9049	5011	ZFW
FSS	HD	BCE-A	BRYCE	UT	[illegible]	[illegible]	ZLA
FSS	HD	CDC-A	CEDAR CITY	UT	8272	7121	ZLA
ARTS	RO	SLC1A	SALT LAKE CITY	UT	7576	7055	ZLC

AREA A NODES: TOTAL 294 (Continued)

FAC	TR	LID	CITY	ST	VER	HOR	CTR
ARTS	HD	SLC2A	SALT LAKE CITY	UT	7576	7065	ZLC
AMOS	HD	ENV-A	WENDOVER	UT	7651	7414	ZLC
ARTS	RO	IAD-A	CHANTILLY	VA	5653	1647	ZDC
FSS	HD	DAN-A	DANVILLE	VA	6270	1640	ZDC
NAS?AW	HD	NGU-A	NORFOLK NAS	VA	5913	1223	ZDC
ARPT	RO	BTV-A	BURLINGTON	VT	4270	1808	ZBW
FSS	HD	EPH-A	EPHRATA	WA	6361	8432	ZSE
FSS	HD	HQM-A	HOQUIAM	WA	6491	9108	ZSE
LAWRS	HD	BFI-A	SEATTLE-BOEING	WA	6336	8896	ZSE
FSS	RO	TDO-A	TOLEDO	WA	6599	8955	ZSE
FSS	HD	EAU-A	EAU CLAIRE	WI	5699	4261	ZMP
FSS	HD	LSE-A	LA CROSSE	WI	5874	4133	ZMP
FSS	HD	LNR-A	LONE ROCK	WI	5824	3922	[illegible]
TWR?LA	HD	CKB-A	CLARKSBURG	WV	5865	2095	ZOB
FSS	HD	EKN-A	ELKINS	WV	5894	1984	ZDC
FSS	HD	HTS-A	HUNTINGTON	WV	6227	2318	ZID
COMCO	HD	RWH-A	MARTINSBURG	WV	5611	1793	ZDC
FSS	HD	MGW-A	MORGANTOWN	WV	5764	2083	ZOB
CST	HD	HLG-A	WHEELING	WV	5755	2241	ZOB
FSS	HD	LAR-A	LARAMIE	WY	7204	6091	ZDV
FSS	HD	RWL-A	RAWLINS	WY	7177	6377	ZLC
FSS	HD	RKS-A	ROCK SPRINGS	WY	7300	6679	ZLC
FSS	HD	SHR-A	SHERIDAN	WY	6535	6505	ZLC
FSS	HD	WRL-A	WORLAND	WY	6740	6613	ZLC

AREA A NODES: TOTAL 294 (Concluded)

FAC	TR	LID	CITY	ST	VER	HOR	CTR
FSS	HD	ADK-R	ADAK	AK	736	6413	ZAN
FSS	HD	ANI-R	ANIAK	AK	2169	3832	ZAN
FSS	HD	BRW-R	BARROW	AK	0	[illegible]	ZAN
FSS	HD	CDV-R	CORDOVA	AK	0	[illegible]	ZAN
FSS	HD	SCC-R	DEADHORSE	AK	1986	2215	ZAN
FSS	HD	HOM-R	HOMER	AK	0	[illegible]	ZAN
FSS	HD	JNU-R	JUNEAU	AK	1598	1058	ZAN
FSS	HD	KTN-R	KETCHIKAN	AK	0	0	ZAN
FSS	HD	ADQ-R	KODIAK	AK	0	0	ZAN
FSS	HD	OTZ-R	KOTZEBUE	AK	2355	3565	ZAN
FSS	HD	MCG-R	MCGRATH	AK	2419	3399	ZAN
FSS	HD	OME-R	NOME	AK	0	0	ZAN
FSS	HD	ORT-R	NORTHWAY	AK	2461	[illegible]	ZAN
FSS	HD	PAQ-R	PALMER	AK	[illegible]	[illegible]	ZAN
FSS	HD	SIT-R	SITKA	AK	[illegible]	[illegible]	ZAN
FSS	HD	YAK-R	YAKUTAT	AK	0	[illegible]	ZAN
FSS	HD	DHN-R	DOTHAN	AL	7331	1983	ZJX
FSS	HD	MGM-R	MONTGOMERY	AL	7392	2247	ZTL
FSS	HD	TCL-R	TUSCALOOSA	AL	7643	2535	ZTL
FSS	HD	ELD-R	EL DORADO	AR	8051	3376	ZFW
FSS	HD	FYV-R	FAYETTEVILLE	AR	7600	3872	ZME
FSS	HD	HRO-R	HARRISON	AR	7490	3718	ZME
FSS	HD	JBR-R	JONESBORO	AR	7380	3297	ZME
AFB/AW	HD	LRF-R	LITTLE ROCK AFB	AR	7685	3433	ZME
FSS	HD	PBF-R	PINE BLUFF	AR	7803	3359	ZME
FSS	HD	DUG-R	DOUGLAS	AZ	9466	6182	ZAB
APT	HD	INW-R	WINSLOW	AZ	8744	6565	ZAB
FSS	HD	YUM-R	YUMA	AZ	9385	7171	ZLA
FSS	HD	ACV-R	ARCATA	CA	7841	9063	ZOA
FSS	HD	BLH-R	BLYTHE	CA	9194	7206	ZLA
FSS	HD	CEC-R	CRESENT CITY	CA	7645	9038	ZSE
FSS	HD	DAG-R	DAGGETT	CA	8995	7591	ZLA
FSS	HD	FUL-R	FULLERTON	CA	9244	7913	ZLA
FSS	HD	FUL-R	FULLERTON	CA	9244	7913	ZLA
FSS	HD	MYV-R	MARYSVILLE	CA	8182	8612	ZOA
FSS	HD	SIY-R	MONTAGUE	CA	7631	8521	ZSE
FSS	HD	EED-R	NEEDLES	CA	8931	7263	ZLA
ATCT	HD	SFO-R	SAN FRANCISCO	CA	8525	8717	ZOA
ATCT	HD	SMX-R	SANTA MARIA	CA	9073	8299	ZLA
FSS	HD	AKO-R	AKRON	CO	7326	5642	ZDV
FSS	HD	EGE-R	EAGLE	CO	7606	6190	ZDV
FSS	HD	LHX-R	LA JUNTA	CO	7756	5501	ZDV
TRCAB	HD	PUB-R	PUEBLO	CO	7787	5742	ZDV
FSS	HD	TAD-R	TRINIDAD	CO	8009	5654	ZDV
FSS	HD	DCA-R	WASHINGTON	DC	5632	1591	ZDC

REQUEST/REPLY NODES: TOTAL 191

FAC	TP	LID	CITY	ST	VER	HOR	CTR
FSS	HD	CEW-R	CRESTVIEW	FL	9025	1128	[illegible]
FSS	HD	EYW-R	KEY WEST	FL	8745	[illegible]	[illegible]
AFB	HD	MCO-R	MCCOY AFB	FL	7954	1091	ZMA
FSS	HD	PNS-R	PENSACOLA	FL	[illegible]	[illegible]	[illegible]
ARPT	HD	PBI-R	WEST PALM BEACH	FL	8166	[illegible]	ZMA
FSS	HD	ABY-R	ALBANY	GA	7349	1917	[illegible]
FSS	HD	AMG-R	ALMA	GA	7498	1599	ZJX
FSS	HD	ATL-R	ATLANTA	GA	7260	2083	ZTL
FSS	HD	[illegible]	BRUNSWICK	GA	7468	1320	ZJX
ATCT	HD	FTY-R	FULTON COUNTY	GA	7260	2083	ZTL
FSS	HD	MCN-R	MACON	GA	7364	1865	ZTL
FSS	HD	VLD-R	VALDOSTA	GA	7709	1594	[illegible]
FSS	HD	OTM-R	OTTUMWA	IA	6500	4042	ZAU
FSS	HD	IDA-R	IDAHO FALLS	ID	6999	7214	ZLC
TRACO	HD	PIA-R	PEORIA	IL	7027	4203	ZAU
FSS	HD	IND-R	INDIANAPOLIS	IN	6272	2991	ZID
FSS	HD	DDC-R	DODGE CITY	KS	7640	4958	ZKC
FSS	HD	EMP-R	EMPORIA	KS	7173	4394	ZKC
FSS	HD	GLD-R	GOODLAND	KS	7414	5345	ZDV
FSS	HD	HLC-R	HILL CITY	KS	7304	5051	ZDV
FSS	HD	MHK-R	MANHATTAN	KS	7149	4520	ZKC
FSS	HD	RSL-R	RUSSELL	KS	7342	4855	ZKC
FSS	HD	SLN-R	SALINA	KS	7275	4656	ZKC
FSS	HD	PAH-R	PADUCAH	KY	6992	3088	ZME
TRACO	HD	BTR-R	BATON ROUGE	LA	8476	2874	ZHU
FSS	HD	ESF-R	ESLER	LA	8409	[illegible]	ZHU
FSS	HD	LFT-R	LAFAYETTE	LA	8587	2996	ZHU
FSS	HD	LCH-R	LAKE CHARLES	LA	8679	3202	ZHU
FSS	HD	MLU-R	MONROE	LA	8148	3218	ZFW
ATCT	HD	ORH-R	WORCESTER	MA	4513	1330	ZBW
FSS	HD	BGR-R	BANGOR	ME	3777	1302	ZBW
FSS	HD	HUL-R	HOULTON	ME	3465	1411	ZBW
FSS	HD	CMX-R	HOUGHTON	MI	5052	4083	ZMP
FSS	HD	JXN-R	JACKSON	MI	5663	3009	ZOB
FSS	HD	LAN-R	LANSING	MI	5584	3081	ZOB
FSS	HD	MQT-R	MARQUETTE	MI	5103	3895	ZMP
FSS	HD	PLN-R	PELLSTON	MI	5074	3422	ZMP
FSS	HD	SSM-R	SAULT STE MARIE	MI	4863	3471	ZMP
FSS	HD	TVC1R	TRAVERSE CITY	MI	5294	3447	ZMP
FSS	HD	TVC2R	TRAVERSE CITY	MI	5294	3447	ZMP
FSS	HD	RST-R	ROCHESTER	MN	5915	4305	ZMP
FSS	HD	JLN-R	JOPLIN	MO	7421	4015	ZKC
FSS	HD	VIH-R	VICHY	MO	7024	3675	ZKC
FSS	HD	MCB-R	MCCOMB	MS	8212	2823	ZHU
FSS	HD	MEI-R	MERIDIAN	MS	7893	2639	ZME

REQUEST/REPLY NODES: TOTAL 191 (Continued)

FAC	TP	LID	CITY	ST	VER	HOR	CTR
FSS	HD	BIL-R	BILLINGS	MT	[illegible]	6790	ZLC
FSS	HD	BZN-R	BOZEMAN	MT	6485	7186	ZLC
FSS	HD	BTM-R	BUTTE	MT	6480	7395	ZLC
FSS	HD	CTB-R	CUT BANK	MT	5911	7479	ZLC
FSS	HD	LWT-R	LEWISTOWN	MT	6152	6990	ZLC
FSS	HD	LVM-R	LIVINGSTON	MT	6488	7089	ZLC
FSS	HD	MLS-R	MILES CITY	MT	6155	6433	ZLC
FSS	HD	MSO-R	MISSOULA	MT	6336	7650	ZLC
ARPT	HD	AVL-R	ASHEVILLE	NC	6766	1993	ZTL
FSS	HD	ECG-R	ELIZABETH CITY	NC	6010	1144	ZDC
APT	HD	42A-R	HIGH POINT	NC	6442	1657	ZTL
FSS	HD	RWI-R	ROCKY MOUNT	NC	6232	1329	ZDC
ARPT	HD	ILM-R	WILMINGTON	NC	6557	1143	ZDC
FSS	HD	DIK-R	DICKINSON	ND	5922	6024	ZMP
FSS	HD	JMS-R	JAMESTOWN	ND	5713	5450	ZMP
FSS	HD	MOT-R	MINOT	ND	5573	5906	ZMP
FSS	HD	CDR-R	CHADRON	NE	6767	5786	ZDV
FSS	HD	BFF-R	SCOTTSBLUFF	NE	6997	5825	ZDV
FSS	HD	SNY-R	SIDNEY	NE	7112	5671	ZDV
FSS	HD	LEB-R	LEBANON	NH	4326	1584	ZBW
FSS	HD	CNM-R	CARLSBAD	NM	8974	5299	ZAB
FSS	HD	DMN-R	DEMING	NM	9129	5914	ZAB
FSS	HD	GUP-R	GALLUP	NM	8555	6273	ZAB
APT	HD	GNT-R	GRANTS	NM	8591	6099	ZAB
FSS	HD	LVS-R	LAS VEGAS	NM	8370	5676	ZAB
FSS	HD	ROW-R	ROSWELL	NM	8787	5413	ZAB
ATCT	HD	SAF-R	SANTA FE	NM	8363	5804	ZAB
FSS	HD	TCS-R	TRUTH OR CONSEQ	NM	8934	5875	ZAB
FSS	HD	TCC-R	TUCUMCARI	NM	8371	5322	ZAB
FSS	HD	EKO-R	ELKO	NV	7682	7699	ZLC
FSS	HD	ELY-R	ELY	NV	7997	7492	ZLC
FSS	HD	LOL-R	LOVELOCK	NV	7892	8121	ZOA
FSS	HD	TPH-R	TONOPAH	NV	8319	7843	ZLC
FSS	HD	GFL-R	GLEN FALLS	NY	4514	1704	ZBW
FSS	HD	MSS-R	MASSENA	NY	4349	2078	ZBW
ARTS	HD	JNY-R	NEW YORK	NY	4997	1406	ZNY
ART	HD	ART-R	WATERTOWN	NY	4618	2100	ZNY
FSS	HD	ART-R	WATERTOWN	NY	4618	2100	ZBW
FSS	HD	YNG-R	YOUNGSTOWN	OH	5548	2348	ZOB
FSS	HD	ZZV1R	ZANESVILLE	OH	5890	2410	ZID
FSS	HD	ZZV2R	ZANESVILLE	OH	5890	2410	ZID
FSS	HD	GAG-R	GAGE	OK	7917	4808	ZKC
FSS	HD	HBR-R	HOBART	OK	8149	4643	ZFW
FSS	HD	MLC-R	MCALESTER	OK	7936	4039	ZFW
AEROCT	HD	OEX-R	OKLAHOMA CITY	OK	7947	4373	ZFW

REQUEST/REPLY NODES: TOTAL 191 (Continued)

FAC	TR	ID	CITY	ST	VER	HOR	CTR
FSS	HD	PNC-R	PONCA CITY	OK	[illegible]	[illegible]	ZKC
FSS	HD	BKE-R	BAKER	OR	6380	9158	ZLC
ATCT	HD	EUG-R	EUGENE	OR	7128	8954	ZSE
FSS	HD	DLS-R	THE DALLES	OR	6762	[illegible]	ZSE
FSS	HD	AOO-R	ALTOONA	PA	5491	1937	ZOB
FSS	HD	BFD-R	BRADFORD	PA	5221	2182	ZOB
FSS	HD	DUJ-R	DUBOIS	PA	5397	2135	ZOB
FSS	HD	ERI-R	ERIE	PA	[illegible]	2397	ZOB
FSS	HD	JST-R	JOHNSTOWN	PA	5542	2021	ZOB
FSS	HD	PSB-R	PHILIPSBURG	PA	5375	1995	ZNY
FSS	HD	IPT-R	WILLIAMSPORT	PA	5200	[illegible]	ZNY
FSS	HD	AND-R	ANDERSON	SC	6961	1394	ZTL
ARPT	HD	GMU-R	GREENVILLE	SC	6873	1394	ZTL
FSS	HD	CRE-R	NORTH MYRTLE BE	SC	6708	1206	ZJX
FSS	HD	ABR-R	ABERDEEN	SD	5992	5309	ZMP
FSS	HD	PIR-R	PIERRE	SD	6316	5497	ZMP
FSS	HD	RAP-R	RAPID CITY	SD	6519	5903	ZDV
FSS	HD	ATY-R	WATERTOWN	SD	6029	5065	ZMP
FSS	HD	DYR-R	DYERSBURG	TN	7245	3297	ZME
FSS	HD	MKL-R	JACKSON	TN	7282	2976	ZME
FSS	HD	ABI-R	ABILENE	TX	8698	4513	ZFW
FSS	HD	ALI-R	ALICE	TX	9533	3855	ZHU
FSS	HD	CDS-R	CHILDRESS	TX	8329	4743	ZFW
FSS	HD	CLL-R	COLLEGE STATION	TX	8827	3798	ZHU
FSS	HD	COT-R	COTULLA	TX	9476	4120	ZHU
FSS	HD	DHT-R	DALHART	TX	8129	5249	ZAB
FSS	HD	GLS-R	GALVESTON	TX	8985	3397	ZHU
FSS	HD	LBB-R	LUBBOCK	TX	8598	4962	ZFW
FSS	HD	LFK-R	LUFKIN	TX	8575	3561	ZHU
FSS	HD	MFE-R	MCALLEN	TX	9856	3764	ZHU
FSS	HD	MWL-R	MINERAL WELLS	TX	8520	4251	ZFW
FSS	HD	PSX-R	PALACIOS	TX	9208	3600	ZHU
ATCT	HD	SJT-R	SAN ANGELO	TX	8944	4563	ZFW
FSS	HD	SPS-R	WICHITA FALLS	TX	8326	4413	ZFW
FSS	HD	INK-R	WINK	TX	9049	5061	ZFW
FSS	HD	BCE-R	BRYCE CANYON	UT	9253	6965	ZLA
FSS	HD	CDC-R	CEDAR CITY	UT	8272	7121	ZLA
FSS	HD	DAN-R	DANVILLE	VA	6270	1640	ZDC
ARPT	HD	BTV-R	BURLINGTON	VT	4270	1308	ZBW
FSS	HD	EPH-R	EPHRATA	WA	6361	8482	ZSE
FSS	HD	HQM-R	HOQUIAM	WA	6491	9108	ZSE
ARPT	HD	OLM-R	OLYMPIA	WA	6469	8971	ZSE
FSS	HD	TDO-R	TOLEDO	WA	6599	8955	ZSE
FSS	HD	EAU1R	EAU CLAIRE	WI	5698	4261	ZMP
FSS	HD	EAU2R	EAU CLAIRE	WI	5693	4261	ZMP

REQUEST/REPLY NODES: TOTAL 191 (Continued)

FAC	TR	LID	CITY	ST	VER	HOR	CTR
FSS	HD	LSE-R	LA CROSSE	WI	537[illegible]	41[illegible]	ZMP
FSS	HD	LNR-R	LONE ROCK	WI	5924	3922	ZAU
FSS	HD	EKN-R	ELKINS	WV	5[illegible]4	1984	ZDC
FSS	HD	HTS-R	HUNINGTON	WV	6227	2318	ZID
FSS	HD	MGW-R	MORGANTOWN	WV	[illegible]764	2083	ZOB
FSS	HD	LAR1R	LARAMIE	WY	7204	6091	ZDV
FSS	HD	LAR2R	LARAMIE	WY	7204	6091	ZDV
FSS	HD	RWL-R	RAWLINS	WY	7177	6377	ZLC
FSS	HD	RKS-R	ROCK SPRINGS	WY	7300	66[illegible]	ZLC
FSS	HD	SHR-R	SHERIDAN	WY	6535	6505	ZLC
FSS	HD	WRL-R	WORLAND	WY	6740	661[illegible]	ZLC

REQUEST/REPLY NODES: TOTAL 191 (Concluded)

FAC	TR	LID	CTY	ST	VER	HOR	CTR
ARTCC	FD	ZAN-Z	ANCHORAGE	AK	0	0	ZAN
ARTCC	FD	ZLA-Z	LOS ANGELES	CA	9094	7873	ZLA
ARTCC	FD	ZOA-Z	OAKLAND	CA	8536	8645	ZOA
ARTCC	FD	ZDV-Z	DENVER	CO	7419	5943	ZDV
ARTCC	FD	ZDC-Z	WASHINGTON	DC	5634	1655	ZDC
ARTCC	FD	ZJX-Z	JACKSONVILLE	FL	7605	1357	ZJX
ARTCC	FD	ZMA-Z	MIAMI	FL	8351	527	ZMA
ARTCC	FD	ZTL-Z	ATLANTA	GA	7320	2028	ZTL
ARTCC	FD	ZAU-Z	CHICAGO	IL	6062	3511	ZAU
ARTCC	FD	ZID-Z	INDIANAPOLIS	IN	6272	2992	ZID
ARTCC	FD	ZMP-Z	MINNEAPOLIS	MN	5838	4477	ZMP
ARTCC	FD	ZBW-Z	BOSTON	NH	4394	1356	ZBW
ARTCC	FD	ZAB-Z	ALBUQUERQUE	NM	8549	5887	ZAB
ARTCC	FD	ZNY-Z	NEW YORK	NY	4994	1301	ZNY
ARTCC	FD	ZOB-Z	CLEVELAND	OH	5659	2594	ZOB
ARTCC	FD	ZME-Z	MEMPHIS	TN	7471	3125	ZME
ARTCC	FD	ZFW-Z	FORT WORTH	TX	8447	4092	ZFW
ARTCC	FD	ZHU-Z	HOUSTON	TX	8892	3556	ZHU
ARTCC	FD	ZLC-Z	SALT LAKE CITY	UT	7576	7065	ZLC
ARTCC	FD	ZSE-Z	SEATTLE	WA	6401	8875	ZSE

ARTCC SERVICE A NODES: TOTAL 20

APPENDIX E

PRESENT VALUE CONCEPT

In order to provide a uniform basis for cost comparisons all costs incurred over the lifetime of each alternative were reduced to a single value called the present value (PV) of the alternative (cf. reference G & C). This represents the amount of money which, if placed in an interest bearing account on the first day of the cost cycle will be sufficient to pay all subsequent costs as they come due. This amount is less than the simple sum of all costs. As used in this study PV is determined via

$$PV \quad = \quad F.C. + PVF \bullet (MRC)$$

where

FC = total initial fixed costs of an alternative

PVF = present value factor (discussed below)

MRC = total of all monthly recurring costs

The value of PVF is a function of the annual interest rate r, the frequency of compounding, and the cost life cycle. In this study an annual interest rate of $r = .1$ is used, compounded monthly for a monthly interest rate of $I = r/12 = .0083333$. The cost cycle will be measured in months. The values of PVF for $N = 12K$, $K = 1,...,10$ are shown in Table A-1. The basic fact needed to derive the value of PVF is that to pay a \$1 cost j months in the future a principal of $(1+I)^{-j}$ must be deposited today in an account compounded monthly at monthly interest rate I. For a sequence of monthly \$1 costs over a period of N months the amount to be set aside is precisely the PVF:

$$PVF \quad = \quad \sum_{K=1}^{N} (1+I)^{-K}$$

Rewriting as

$$PVF = \sum_{K=O}^{N} (1+I)^{-K} - 1$$

and summing the geometric series yields

$$PVF = \frac{1-(1+I)^{-(N+1)}}{1-(1+I)^{-1}} - 1$$

Simplifying

$$PVF = \frac{(1+I)^{N}-1}{I(1+I)^{N}}$$

This can be viewed as the conversion factor for converting a stream of equal monthly payments over N months to a single lump sum payment at the start of the period.

APPENDIX F

WMSC-SWITCH LINK AVAILABILITY

Availability of at least one 9.6 kb/s branch of a 19.2 kb/s line

$$= \quad 1-(1-A)(1-A) = .999995$$

where

A = Availability of a 9.6 kb branch including modem and diplexor.

$$A = A_1^2 A_2^2 A_3 = .9977$$

where

A_1 = Availability of Diplexor = .9999

A_2 = Availability of Modem = .99993

A_3 = Availability of a 9.6 kb Transmission Line = .998

Availability of DDS link

$$A = A_I^2 A_{II} = .9978$$

where

A_I = Availability of MUX = .9999

A_{II} = Availability of 50 kb Transmission Line = .998

APPENDIX G

SWITCH TO CONCENTRATOR ANALYSIS

The performance models for message flow from a NADIN switch to a NADIN concentrator is presented in this appendix. In G.1, SAS broadcast is modeled; in G.2, SAS Replies are analyzed and in G.3, low speed replies are discussed. Finally, in G.4, the behavior of NADIN I traffic is examined.

G.1 SAS BROADCAST

The worst case for SAS broadcast is based on the assumption that all 10 queues corresponding to an average concentrator's 10 Service A circuits (3 SAS, 3 Area A, 3 R/R, 1 Z) are busy: that is, have frames requiring transmission to the concentrator. The governing factor in rate of frame transmission is the absorption rate at the local circuit which determines buffer availability. The switch activity can be modeled as follows: at a given instant, assume buffer space for 1 frame has just become available for each local circuit. The switch encountering frames at each queue sends 10 frames in succession. This "long cycle" occupies 10 x .47 = 4.7 seconds.

Without loss of generality, assume the first three queues correspond to Area A circuits, the next three to Request/Reply circuits, the next to a Z-circuit and the last three queues to the medium-speed SAS circuits. At the conclusion of a long cycle, the switch returns to the 1st queue but cannot service it because buffer space will not become available at Area A Buffer Number 1 for another 23.3 seconds. Similarly, no other frames can be sent to low-speed addresses. Hence, the switch returns to the SAS queues. However, only 1.41 seconds have elapsed since the first SAS frame was serviced in the preceding long cycle. Because of the initial assumptions and the fact that the medium-speed lines require 1.46 seconds to absorb a frame, buffer space will not be available at the first SAS concentrator port for another .05 seconds. Thus, the first short cycle commences with an idle of .05 seconds followed by transmission of three SAS frames (1.41 sec) for a total time of 1.46 seconds. The switch again returns to the low-speed output queues but cannot service them because buffer space is not available at the concentrator. After 1 long cycle and 15.3

short cycles, the first low-speed (Area A) local circuit has absorbed one frame and hence can receive a new frame from the switch.

At the completion of one long cycle and 16 short cycles the switch once again transmits low-speed frames and a long cycle occurs. The actual sequence of events may differ somewhat from this conceptualization but the effect in terms of frame transmission is approximately correct. This sequence is illustrated in Figure G-1.

Using the model described above, the mean service time for the transmission of a single SAS broadcast frame is:

$$MST_{fr} = (28.06)/17 = 1.65 \text{ sec./fr.}$$

Using the value of MST_{fr} for SAS broadcast, it is possible to determine the throughput rate in Kb/s using the number of data bits per frame to find the SAS broadcast throughput (Th) under busiest or worst conditions which is given by:

$$Th = \frac{D_1 + (N-1) \bullet D_2}{MST_{fr} \bullet N \bullet 1000}$$

where

D_1 = Data bits in 1st frame of broadcast message = 1400

D_2 = Data bits in subsequent frames = 1850

N = Number of frames per broadcast message = 16

These values yield Th = 1.1 Kb/s for worst case.

The best case assumes again that all three Area A and all three SAS queues are constantly occupied (as is actually the case during broadcast periods) but that the Request/Reply and Z queues are completely idle. Then the same type of analysis can be used as for the worst case. The only difference is that a "long" cycle requires only 2.82 seconds, so that 16.5 short cycles (still 1.46 seconds long) occur before low-speed buffer space becomes available. This shows that the mean service time for an SAS broadcast frame under best case assumptions is:

$$MST_{fr} = 27 \bullet (1 + 16.5)^{-1} = 1.54 \text{ sec./fr.}$$

The small variation between best and worst case results for SAS broadcast is due to the fact that the switch spends a small percentage (5 percent) of its time on frames to low-speed (Request/Reply) circuits even under busiest conditions.

The delay encountered by the first frame of an SAS broadcast message under worst case conditions is less than 1.65 seconds.

G.2 SAS REPLIES FROM SWITCH TO CONCENTRATOR

The results in Section 4.3.1.3 are derived from two M/M/1 queue models (see Kleinrock), one for worst case and one for best case. In both cases the conservative assumption is that all Area A queues are occupied. Request/Reply traffic flows on local SAS circuits only when broadcast is not occurring. The assumption is made, therefore, that all SAS reply traffic occurs during the approximately 50 minutes of the hour in which there is no SAS broadcast.

In both cases, the 3 SAS queues associated with an average center are treated as a single queue. Interarrival times are assumed exponential with mean equal to the sum of the three individual arrival rates. The service times for both cases are assumed to be exponentially distributed with mean service rates described below. Care is required to derive an appropriate concept of mean service rate in this model.

For the worst case, it is assumed that all Request/Reply and Z queues are busy in addition to the Area A queues. This leads to a mean arrival rate for SAS frames of λ = .372 fr./sec., and a mean service rate μ = 1.87 fr./sec.

For the best case, it is assumed that all Request/Reply and Z queues are idle, but Area A queues are busy. The mean arrival rate is unchanged λ = .372 fr./sec. but the mean service rate is μ = 2.02 fr./sec.

The mean service rates are obtained by considering a 27 sec. cycle and determining the percentage of time during the cycle that low-speed buffer space is available. When low-speed buffer space is not available, the SAS frames are serviced at the rate of $(.47)^{-1}$ = 2.13 fr./sec.

In worst case, 7 low-speed lines are assumed busy so that low-speed buffer space is available an average of:

$$\frac{(7)\,(.47)}{27} = .12$$

of the time. Assuming that during this time SAS reply frames are not serviced, a conservative mean service rate μ is given as:

$$\mu = (.88)(2.13) = 1.87 \text{ fr./sec.}$$

In the best case, 3 low-speed lines are in operation, so buffer space for low-speed frames is available during .05 of the cycle. Hence, the mean service rate μ becomes:

$$\mu = (.95)(2.13) = 2.02 \text{ fr./sec.}$$

To obtain W_q, the mean time spent waiting in the queue, the standard M/M/1 formula is used,

$$W_q = \text{MST} \bullet \frac{\rho}{1-\rho}$$

where

$$\rho = \frac{\lambda}{\mu} = \text{traffic intensity.}$$

The delay exceeding that experienced by 90 percent of SAS frames is obtained as in Appendix H. For the worst case, the $90^{\underline{th}}$ percentile total delay is .99 seconds, of which .46 seconds is queueing wait. For the best case, the $90^{\underline{th}}$ percentile total delay is .86 seconds, including a .37 seconds queue wait.

Finally, the delay of the first frame represents essentially the entire delay contributed by the switch-to-concentrator transmission because subsequent frames of the reply are transmitted with no delay visible to the user. This is because the abs[illegible]on rate of 1.46 sec/fr. is significantly slower than the mean service time for a fram[illegible] .53 seconds.

G.3 LOW SPEED REQUEST/REPLY DELAYS FROM SWITCH TO CONCENTRATOR

The results in Section 4.3.1.4 are obtained by following an analysis similar to that in Section G.2. The three Request/Reply queues of the average center are treated as a single

queue having Poisson arrival with mean $\lambda = .04$ fr./sec. This is determined by taking three times the mean arrival rate for a single low-speed Reply queue at the switch. The service time distributions are assumed to be exponential for both cases. The derivations of the mean service rates are discussed in the remainder of this section.

For the worst case it is assumed that all 3 SAS, all 3 Area A, and 1 Z queue are busy (broadcast period). Under zero input from the Request/Reply queue, the switch will proceed much as in the SAS broadcast model; that is, one long cycle in which 7 frames are sent followed by 17 short cycles in which 3 frames are sent (to SAS buffers). One can determine an expected wait for service (EWS) which is the time a Reply frame in the joint low-speed R/R queue must wait for attention from the switch, assuming no other replies in the queue.

$$EWS = (W_S \bullet P_S) + (W_L \bullet P_L) = .86 \text{ sec.}$$

where

W_S = average wait for service in short cycle = $(.5) \bullet L_S$ = .75 sec.

L_S = time required to send 3 SAS frames = 1.41 sec.

P_S = probability that switch is in short cycle = .88.

W_L = average wait for service in long cycle = $(.5) \bullet L_L$ = 1.64 sec.

L_L = length of long cycle = $7 \bullet (.47)$ = 3.29 sec.

P_L = probability that switch is in long cycle = .12.

The mean service time for a frame (MST_{fr}) in worst case is now obtained from:

$$MST_{fr} = EWS + T_{fr} = 1.33 \text{ sec.}$$

where

T_{fr} = time to send one frame = .47 sec.

The value of μ, the mean service rate in worst case is

$$\mu = (MST_{fr})^{-1} = .75 \text{ fr./sec.}$$

In the best case for low-speed reply analysis, it is assumed that 3 Area A queues and the Z queue are full constantly, and the SAS queues are handling reply frames but not broadcast frames. As seen in the preceding section, SAS reply traffic uses 20 percent of actual switch-to-concentrator capacity while Area A traffic uses 7 percent. Therefore, an expected wait for service EWS can be defined as:

$$EWS = (T_{fr} \bullet P_S) + (T_{fr} \bullet P_A) = .13 \text{ sec.}$$

where

P_S = probability that switch is sending SAS frame = .2

P_A = probability that switch is sending Area A or Z frame = .07

T_{fr} = time to send one frame = .47 sec.

The value of the mean service time per frame MST_{fr} is given by:

$$MST_{fr} = EWS + T_{fr} = .60 \text{ sec.}$$

The value of the mean service rate μ for best case is

$$\mu = (MST_{fr})^{-1} = 1.69 \text{ fr./sec.}$$

To obtain W_q, the mean time spent waiting in the queue, the formula:

$$W_q = MST_{fr} \bullet \frac{\rho}{1-\rho}$$

is again used.

Most of the delay for low-speed replies is caused by the Mean Service Time—not W_q, the mean wait in the queue. In fact, the $90^{\underline{th}}$ percentile wait in the queue is zero for both the best and worst cases.

G.4 NADIN I DELAYS FROM SWITCH TO CONCENTRATOR

To investigate the effect of Service A traffic on any one of the ten different categories of NADIN I switch output ports, proceed as follows: treat all NADIN I traffic other than the specific destination traffic being analyzed as overhead on the link from switch to concentrator. As an example, a typical Area B (75 b/s) circuit has associated with it an output queue at the switch. The switch is viewed as cyclically serving the 10 Service A output queues as in Figure 4.2 with an added queue (Area B) at the top (or bottom). An Area B (or any other NADIN I Type II message frame) upon arriving at the head of its own queue must wait for attention from the switch. To obtain bounds on the worst delays, it is assumed that the frame arrives during a period of Service A broadcast to both low- and medium-speed circuits. An expected wait for service (EWS) is determined by:

$$EWS = W_S \bullet P_S + W_L \bullet P_L = .87 \text{ sec.}$$

where

W_L = wait for service during long cycle (as in Section 4.2.3)

= $(.5) \bullet (EL_L)$

P_L = probability of a long cycle = .14

W_S = wait for service during short cycle = $(.5) \bullet (EL_S)$

P_S = probability of a short cycle = .86.

The terms EL_L and EL_S are the expected lengths of long and short cycles, respectively. So that EL_S = time for 3 SAS frames = 1.41 sec. On the other hand, EL_L is the time to send 3 SAS frames, 3 Area A frames, and one Z (ARTCC) frame plus the

expected usage of three R/R circuits which is approximately .33 frames per circuit in a 27 second period. Therefore:

$$EL_L = 3.8 \text{ sec.}$$

This value for EWS can be used in turn to examine individually each of the various NADIN I circuits.

For Type II traffic the average message length is 120 characters or approximately ½ of a full-sized frame. Denote by T'_{fr} the time to send such an average frame on the 4.8 Kb/s switch-to-concentrator link.

$$T'_{fr} = .32 \text{ sec.}$$

For Type II messages the Mean Service Time is thus:

$$MST = EWS + T'_{fr} = 1.19 \text{ sec.}$$

The mean service rate μ is then given by:

$$\mu = (MST)^{-1} = .84 \text{ msg/sec.}$$

The NADIN I queue under examination (e.g., an Area B queue) can now be treated as an M/M/1 queue with $\mu = .84$ and λ determined from the traffic table in Appendix Z, NADIN Specifications. For example, for a typical Area B circuit $\lambda = .0044$ msg/sec. For the standard M/M/1 queue model being used, the formula for the waiting time in the queue is given by:

$$W_q = (MST) \bullet \frac{\rho}{1-\rho}$$

where

$$\rho = \frac{\lambda}{\mu} = \text{traffic intensity.}$$

For Area B the value of W_q = .006 sec. Delay is given by the formula:

$$\text{Delay} = \text{MST} + W_q$$

So that for Area B the average delay from switch-to-concentrator is approximately 1.2 seconds.

By substituting the appropriate arrival rates λ into this model the delays for all Type II NADIN I traffic for FOT, Local DTE, Remote DTE, Area B, Military B, AFTN, Air B and Utility B and MAPS are obtained.

The International AFTN traffic can be analyzed similarly to the above, except that T_{fr} = .47 sec. and λ = .033 fr/sec. is the mean arrival rate. The value of MST = 1.34 sec. The M/M/1 queue model implies a wait W_q = .06 sec. and a total average delay of 1.4 sec. Since International AFTN traffic is addressed to low-speed (75 b/s) terminals subsequent frame delays at the switch will not result in delays at the final destination.

The last category of NADIN I port is the one for the 9020. Most Type II traffic has priority over the long-message Type III traffic. NADIN I Type II traffic from the WMSC would have Priority Level 4 but since the origin of Type II traffic is difficult to ascertain at this time, the assumption made above is used since it gives conservative results for Type III delay and has little effect on Type II delays. Hence the delays for Type II 9020 traffic can be obtained using the same model as developed for the other Type II traffic. In particular, the MST = 1.19 sec. Using λ = .095 msg/sec. leads to the values W_q = .15 seconds, Type II message average delay = 1.34 sec. If Type III 9020 traffic arrives at the output queue at the switch it must wait until all higher priority Type II messages are served. If no Type II messages are in queue, then the Type III message incurs a delay in attention from the switch due solely to the Service A and overhead factors. Define the expected wait for service (EWS) for the Type III message via:

$$\text{EWS} = P_{II} \bullet D_{II} + (1-P_{II}) \bullet D_A$$

where

P_{II} = probability that 9020 Type II messages are in the system.

D_{II} = average delay of a Type II message = 1.34 sec.

D_A = Delay due to Service A and overhead if no Type II 9020 traffic is in system.

The value of P_{II} is given by:

$$P_{II} = \frac{(\text{No. of Type II msg/hr.}) \bullet D_{II}}{3600} = .13$$

The resulting value of EWS for Type III 9020 traffic is .93 sec. From this the value of:

$$MST = EWS + T_{fr} = 1.4 \text{ sec}$$

is readily obtained. Now the M/M/1 queue model is used with $\mu = (1.4)^{-1} = .72$ fr/sec., $\lambda =$ .012 fr/sec. so that $W_q = .03$ sec. and the average delay is 1.43 seconds for Type III 9020 traffic from switch to concentrator during the busiest broadcast period of Service A.

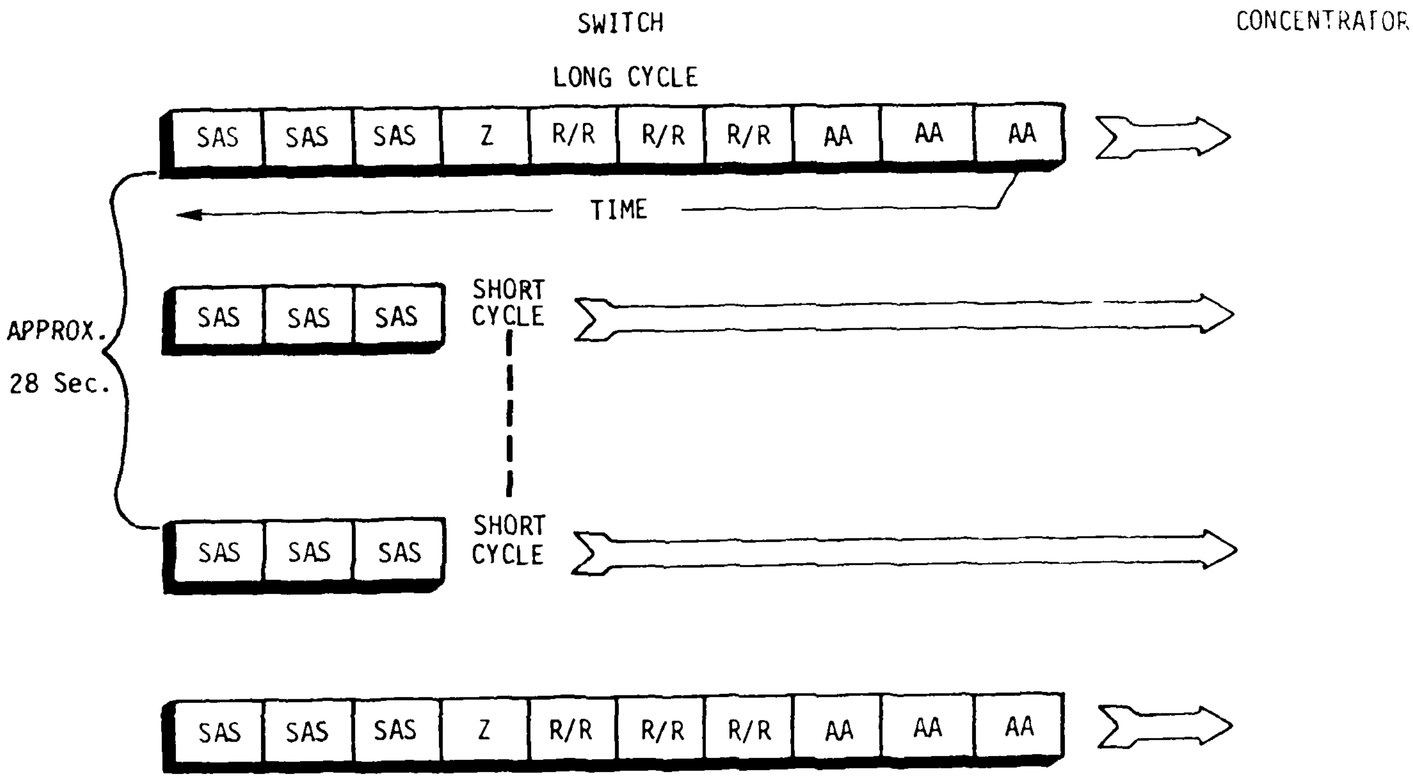


FIGURE G-1: SWITCH OPERATION MODELED FOR SAS BROADCAST EVALUATION

APPENDIX H

REPLY DELAYS FROM WMSC TO SWITCH

To model the delays reported in Section 4.3.2.3 it is assumed that line 3 from WMSC to Switch acts as an M/M/1 queue, i.e., Poisson arrival process and exponentially distributed service times. Such a model gives reasonably accurate results on the conservative side and so is appropriate in a design effort of this type. To employ the queue model, it is necessary to determine the Mean Service Time (MST) or its recipricol, μ , the mean service rate as well as λ, the mean message arrival rate. The mean arrival rate λ is determined by:

$$\lambda = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 = 1.33 \text{ msg/sec.}$$

where

λ_1 = arrival rate for SAS replies = .92 msg/sec (this is based on the assumption that replies to SAS terminals occur during the approximately 50 min/hr. in which the local circuit is not in use for broadcast or collection of weather products).

λ_2 = arrival rate for low-speed replies = .08 msg/sec

λ_3 = arrival rate for Type II NADIN I traffic = .31 msg/sec

λ_4 = arrival rate for Type III NADIN I traffic = .02 msg/sec

The mean service rate MST is obtained from the equation:

$$MST = (MST_{RP}) \bullet P_{RP} + (MST_{II}) \bullet P_{II} + (MST_{III}) \bullet P_{III}$$

where

MST_{RP} = Mean Service Time for a reply = $(3.5)T_{fr}$ = .364 sec.

MST_{II} = Mean Service Time for a Type II msg = .1 sec.

MST_{III} = Mean Service Time for Type III msg = $(15)T_{fr}$ = 1.56 sec.

P_{RP} = Probability that a message is a reply = .75

P_{II} = Probability that a message is Type II = .23

P_{III} = Probability that a message is Type III = .02

The value of MST is .33 sec/msg.

From MST is obtained the value of μ, the mean service rate via:

$$\mu = (MST)^{-1} = 3 \text{ msg/sec}$$

The wait in the queue W_q is given by the standard M/M/1 formula (see Kleinrock).

$$W_q = (MST) \bullet \frac{\rho}{(1-\rho)}$$

where

$$\rho = \frac{\lambda}{\mu} = .44 \text{ is traffic intensity.}$$

The value of W_q is .26 seconds.

It is now possible to determine the average message delay for each of the types of traffic. The message delay produced at the destination will be due to the delay in receipt of the first frame only. Therefore, the message delay for each of the three types of traffic (Reply, Type II, and Type III) is given by:

Average Delay = T_{fr} + W_q = .37 sec.

These delays are for the period of heaviest traffic, that is during the peak hour for Request/Reply traffic discussed in Appendix P. Performance during other than peak-hours will be significantly better.

The $90^{\underline{th}}$ percentile queue wait for an M/M/1 queue is determined by the formula (cf. Gross and Harris, Fundamentals of Queueing Theory):

$$T_{90} = (\ln(.1) - \ln\rho)/(\lambda - \mu) \text{ if } \rho > .1$$

From this equation the value of T_{90} is found to be:

$$T_{90} = .89 \text{ sec.}$$

Hence

$$90^{\underline{th}} \text{ Delay} = T_{90} + T_{fr} = 1 \text{ sec.}$$

APPENDIX I

NADIN I DELAYS - SWITCH TO SWITCH

The formula for average delay which is used is:

$$\text{Avg. Delay} = MST + W_q$$

where

MST = mean service time for a message

W_q = mean time spent in queue

The value of MST is given by:

$$MST = \frac{(8C)(OH)}{9600} = .175 \text{ sec.}$$

where

C = number of characters in average Type II message (including flag, address, etc.) = 175

OH = ADCCP overhead factor = 1.2

The mean queue wait W_q is determined by the usual M/M/1 model with mean arrival rate :

$$\lambda = \frac{2679 \text{ msg/hr}}{3600 \text{ sec}} = .75 \text{ msg/sec.}$$

and with mean service rate μ

$$\mu \quad = \quad (MST)^{-1} = 5.7 \text{ msg/sec.}$$

The value of W_q is obtained from the formula

$$W_q \quad = \quad \frac{\rho}{\mu(1-\rho)} = .03 \text{ sec.}$$

where

$$\rho \quad = \quad \frac{\lambda}{\mu} = .13 \text{ is the traffic intensity.}$$

The $90^{\underline{th}}$ percentile delay is approximately .23 sec which is computed from:

$$90^{\underline{th}} \text{ percentile delay} = MST + T_{90}$$

where

$$T_{90} \quad = \quad 90^{\underline{th}} \text{ percentile time in queue.}$$

The value for T_{90} for an M/M/1 queue is readily determined by the formula (valid for $\rho > .1$)

$$T_{90} \quad = \quad (\ln(.1) - \ln\rho)(\lambda - \mu) = .05 \text{ sec.}$$

APPENDIX J

NADIN PRIORITY 1 MESSAGE DELAY - WMSC TO SWITCH

The delay of .23 seconds is obtained by determining EWS, the expected wait for service and using the formula:

$$\text{Delay} = \text{EWS} + T_{fr}$$

where

T_{fr} = time to send one frame = .1 sec.

and

$\text{EWS} = P \bullet T_{msg}$ = .12 sec.

Hence

P = probability that the switch-to-concentrator link is busy = .32

T_{msg} = time required to send average reply message = .37 sec.

A Priority 1 message from a NADIN switch to the WMSC would experience a delay smaller than .23 seconds because of the smaller traffic load incoming to the WMSC.

APPENDIX K

BUFFER OCCUPANCY AT THE SWITCH

K.1 Buffer Use for Reply Traffic

The probability that buffer demand at the switch exceeds buffer capacity is computed in this section. Messages considered are the Reply messages addressed to low and medium speed terminals. The waiting time w_j^1 for medium or low speed messages queued for transmission to a single concentrator has the associated probability density function

$$f_i(w) = (1-\rho_i)\delta(t) + \lambda_i(1-\rho_i)e^{-\mu_i(1-\rho_i)t}u_o(t)$$

where

λ_i = frame arrival rate

μ_i = frame service rate

ρ_i = λ_i/μ_i = traffic intensity

The values of λ_i, μ_i, ρ_i were presented in Appendix G.

The probability density function for $w = w'_1 + w'_2$ is denoted f_w and is found from the equation

$$f_w(t) = \mathcal{L}^{-1}\left\{w'^*_1 \bullet w'^*_2\right\}$$

where

$\mathcal{L}^{-1}(Z)$ = Inverse Laplace Transform of

$w_i'^*(s) \quad = \quad$ Laplace Transform of $f_i(t)$.

The expression for f_w obtained in this way is

$$f_w(t) = (1-\rho_1)(1-\rho_2)(\delta(t) + C_1 e^{-At} + C_2 e^{-Dt})$$

where

$$A = \mu_1 (1-\rho_1)$$

$$D = \mu_2 (1-\rho_2)$$

$$C_1 = \lambda_1 + \frac{\lambda_1 \lambda_2}{B-A}$$

$$C_2 = \lambda_2 + \frac{\lambda_1 \lambda_2}{B-A}$$

Total buffer occupancy due to replies destined for 12 concentrators is related to the sum

$$\sum_{i=1}^{12} w_i = W$$

where each $w_i = w$. The buffer usage in Kbytes is related to W by:

$$b = CW$$

where

C = capacity of SWITCH-Concentrator link (Kchar/sec).

The value of C used is (4.8/8) = .6 Kchar, which is higher than the actual data transfer rate (because of protocol overhead etc), in order to overestimate buffer occupancy and to account for NADIN 1 buffer use.

The probability of buffer overflow is given by

$$\text{Prob } (b > B) = \text{Prob } (W > \frac{B}{C}) = \text{ Prob } \frac{W}{12} \cdot \frac{B}{12C})$$

The Chernoff bound estimates probabilities of the form

$$\text{Prob } (\frac{1}{N} \bullet \sum_{i=1}^{N} w_i > d), \quad d > \bar{w}$$

Specifically with $d = \frac{B}{12C}$, the probability of overflow is estimated by

$$E \quad \exp(\lambda_0 (w-d)) \quad ^{12} > \text{Prob } (b > B)$$

with λ_0 defined by

$$\frac{E \quad w \exp(\lambda_0 w)}{E \quad \exp(\lambda_0 w)} = d$$

In particular, use of this estimate yields the result

$$.051 > \text{Prob } (b > 3.8).$$

So that the probability of non overflow due to Service A Reply messages at the switch is approximately .95 with buffer capacity at the switch of 3.8 Kbytes.

K.2 Buffer Use by Broadcast Messages

The buffer occupancy of medium and low speed broadcast frames during the hourly SA broadcast is the maximum buffer demand which will occur in an hour. This use is given in Kilobytes by

$$B_1 = ((S'_{in} - S'_{out}) + (S_{in} - S_{out})) \bullet T_1/8$$

where

S'_{in}	=	WMSC-Switch SAS effective broadcast rate	=	18.46 Kb/sec.
S'_{out}	=	SWITCH to SAS output rate	=	$(12)\bullet(1.1) = 13.2$ Kb/s
S_{in}	=	WMSC-SWITCH Area A broadcast rate	=	2.3 Kb/sec.
S_{out}	=	SWITCH to Area A output rate = $(12)\bullet(.07)$	=	.84 Kb/sec.
T_1	=	time of SA broadcast to SAS circuits	=	125 sec.

The result is

B_1 = 105 Kbytes

B_1 is the additional buffer capacity needed at the switch if no flow control is used to control flow of broadcast messages from the WMSC to Switch.

APPENDIX L

SAS MULTIPOINT CIRCUIT PERFORMANCE ANALYSIS

L.1 Broadcast and Collection

The term information ratio is used here to mean the ratio of information bits which can be successfully transmitted per unit time (including possible retransmission due to error) between node and concentrator to the nominal rated bits per unit time of the line, so that an information ratio of .5 for a 2400 b/s line will mean that 1200 error-free bits per second can be transferred.

The information ratio for schedule collection is based on schedule collection of 48-character messages, the typical SA. The derivations of these information ratios are provided in Appendix L.4 and are, of course, based on a detailed analysis of the ANSI X3.28-2.7 protocol.

The information ratio for 10 nodes per circuit was used together with the traffic totals in Table 4-16 to obtain the performance results of Table 4-11. An example illustrates the method.

The number of minutes per hour that a 10-node SAS circuit is receiving scheduled broadcast is given by:

$$M_B = \frac{T_B}{L \times I.R. \times 60}$$

where

M_B = total minutes per hour in scheduled broadcast

T_B = broadcast Kbits per hour = 580

L = line speed in Kb/sec. = 2.4

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$I.R. \quad = \quad$ information ratio for 10-node SAS circuit = .46

This yields:

$$M_B \quad = \quad 8.76 \text{ minutes.}$$

The other entries in Table 4-11 are computed by the same method except that for "collection" the information ratio .44 is used for all SAS circuits.

L.2 SAS Request/Reply Model

The average delays, D_{RQ} for a request and D_{RP} for a reply given in Table 4-12, are computed as follows:

$$D_{RQ} = W_{RQ} + MST_{RQ}$$

$$D_{RP} = W_{RP} + T'_{RP}$$

where

W_{RQ} = time a request waits in queue at controller (sec.)

MST_{RQ} = mean service time for a request (sec.)

W_{RP} = time a reply waits in queue at concentrator (sec.)

T'_{RP} = time to send first character of Reply from Concentrator to SAS controller

For peak hour traffic the values of W_{RQ}, MST_{RQ}, W_{RP}, and MST_{RP} are displayed in Table 6-3. Further description of these quantities and the method by which they were derived is given in this section.

The Mean Service Time for a request (MST_{RQ}) is the average time in peak hour for the transmission of an error-free request (including retransmission time) to the NADIN concentrator from the SAS controller for a request originating in the 50+ min. per hr. in

which SAS circuits are available to be polled for unscheduled inputs. MST_{RQ} is computed as follows:

$$MST_{RQ} = \frac{(\frac{N-1}{2})T_{NP} + T_{PP} + T_{RQ}}{1-P_{RQ}}$$

where

N = number of controllers per circuit

T_{NP} = time for concentrator to send poll to controller and receive negative response = .194 sec.

T_{PP} = time to send positive poll = .047 sec.

T_{RQ} = time to send request to concentrator and receive acknowledgement of successful transmission (not including possible errors) = .341 sec.

P_{RQ} = probability of an error in request message = .0075.

The quantities T_{NP}, T_{PP}, T_{RQ}, and P_{RQ} depend on the SAS protocol but not on the number of nodes N per circuit. The derivation of these quantities is given in Section L.4. Note that the term $(1-P_{RQ})$ divides the sum of polling times and request transmission. This is because a request received in error by the concentrator must await the next polling cycle to be reattempted.

The Mean Service Time for a reply (MST_{RP}) is the average time in peak hour for a reply message which has just arrived at a concentrator to be sent successfully to a controller. To send a reply to a node, the concentrator must select that node, send the reply, and receive verification from the node of correct reception of the reply. MST_{RP} is computed via:

$$MST_{RP} = \frac{\frac{T_{SEL}}{1-P_S} + T_{RP} + \frac{T_{VER}}{1-P_V}}{1-P_{RP}}$$

where

T_{SEL} = time for concentrator to select a node = .201 sec.

T_{RP} = time for transmission of average reply from concentrator to SAS controller = 2.387 sec.

T_{VER} = time for concentrator to send verification = .201 sec.

P_S = probability of error in selection = .001

P_V = probability of error in verification = .001

P_{RP} = probability of an error in reply message = .0902.

This gives the value

MST_{RP} = 3.07 seconds.

The value of T'_{RP} is given by

$$T'_{RP} = \frac{Tsel}{1-P_s} + t_2 = 2.21$$

where

T'_{RP} = time to complete and send first character of Reply

t_2 = time to transmit first character of reply after successful selection = .02 sec.

Note that MST_{RP} is independent of N, the number of nodes/circuit. The derivations of T_{SEL}, T_{RP}, T_{VER}, P_S, P_V, P_{RP} are given in Appendix L.4.

A request coming to an SAS controller for transmission to its NADIN concentrator and on to the WMSC will experience a delay prior to transmission due to polling and due to unavailability of the SAS circuit for polling because of engagement in a request or reply transmission. The mean queueing wait experienced by a request at an SAS controller can be calculated by treating the local line as a single server queue, (M/M/1) type, with service rate μ_{RQ} given by:

$$\mu_{RQ} = (MST_{RQ} + MST_{RP})^{-1}$$

and arrival rate

$$\lambda_{RQ} = \text{number of requests per second per SAS circuit in peak hour.}$$

The value for λ_{RQ} is given by

$$\lambda_{RQ} = N \times RQ$$

where

N = number of nodes per circuit

RQ number of requests per node per second from Table 4-17. Note that both μ_{RQ} and λ_{RQ} are functions of N.

The waiting time spent due to queueing for a request is now given by

$$W_{RQ}(N) = \frac{1}{\mu} \times \frac{\frac{\lambda}{\mu}}{(1 - \frac{\lambda}{\mu})}$$

This equation generates the values for W_{RQ} in Table L-1.

A reply comes to a NADIN concentrator for transmission to an SAS node. The concentrator stops polling and sends the reply unless another reply is in process of being sent along the local lines. Therefore, the queueing wait W_{RP} experienced by the reply at the

concentrator is determined by the Mean Service Time for Reply, MST_{RP} and by the arrival rate λ_{RP} which depends on N. The queueing model is again a single server M/M/1 queue with service rate:

$$\mu_{RP} = (MST_{RP})^{-1} = .33$$

and arrival rate per second

$$\lambda_{RP} = N \times RP$$

where RP = number of replies per SAS controller per second.

The waiting time in the reply queue at the concentrator is then given by:

$$W_{RP} = \frac{1}{\mu_{RP}} \times \frac{\frac{\lambda_{RP}}{\mu_{RP}}}{(1 - \frac{\lambda_{RP}}{\mu_{RP}})}$$

This formula gives the values in Table L-1 for W_{RP}.

90th Percentile delays are obtained by replacing average queue waits W_{RQ}, W_{RP} in the average delay formulas by 90th percentile queue waits W'_{RQ}, W'_{RP} respectively where

$$W' = (\ln(.1) - \ln \rho)/(\lambda - \mu), \text{ for } \rho > .1$$

where

$$\rho = \lambda / \mu.$$

L.3 SAS Select-Broadcast Procedure

When a broadcast is to be distributed by a NADIN concentrator to an SAS circuit, the concentrator will send a select signal to each controller on the line. Each node upon receipt of the select signal responds with an ACK or NAK to the concentrator. Upon receipt of an

ACK from all stations, the concentrator sends the message down the circuit to all stations. The concentrator then sends a verification request to each node in turn asking it to acknowledge correct receipt of the message.

Messages are sent in blocks of 236 characters plus 4 control characters as follows:

S	B		E	B
O	K	————DATA————	O	C
B	N		B	C

where

SOB	-	Start of Block
BKN	-	Block Number
EOB	-	End of Block
BCC	-	Block Check Character

A maximum value of i = 13 blocks per message transfer is currently permitted by WMSC to SAS nodes. This value i = 13 is assumed to be used by the NADIN concentrator in broadcasts to SAS circuits. The response time for a controller to initiate response to a signal at the controller from the concentrator is assumed to be .1 sec. The times for error-free selection, broadcast and verification are computed in Appendix L.4. From these, the information ratios are derived. It should be noted that if a node has not received a transmission correctly, then the entire message of up to 13 blocks is retransmitted, but to that node only—not to the entire circuit.

L.4 SAS Protocol Analysis

In this section the values of quantities which are dependent on the ANSI X3.8-2.7 protocol are derived. The ASCII code used is an 8 bit per character code. The following can be obtained.

1. T_{SEL} = Time required to select a station

To select a station, the con-entrator will send:

S	S	S			E	N	N
Y	Y	Y			N	U	U
N	N	N	R	*	Q	L	L

an 8 character message (other choices of actual characters may be made). In reply the concentrator receives

S	S	S			A	N	N				N
Y	Y	Y			C	U	U				A
N	N	N	3	*	K	L	L	or	---3	*	K - - -

an 8 character message.

$$T_{SEL} = t_1 + t_2 + t_3 + t_4 + t_5 + t_2$$

where

t_1 = time to transmit select message = .027 sec.

t_2 = local propagation time = .02 sec.

t_3 = terminal response to signal = .1 sec.

t_4 = modem turn on time = .007 sec.

t_5 = time to transmit ACK = .027 sec.

This yields

T_{SEL} = .201 seconds.

This time is the time if errors never occur.

2. T_{VER} = time required to verify a message transfer = .201 sec.

This quantity is computed in the same manner as T_{SEL} since the verification signal and ACK signal have the same length as the select and ACK signals.

3. T_M = time for transmission of a 13 block message ignoring errors.

$$T_M = \frac{(B \bullet i) + C_h}{L} + t_2$$

where

B = bits in a block = 1920

i = number of blocks maximum = 13

C_h = bits in header character = 8

L = line speed = 2400 b/s

t_2 = local propagation time

T_M = 10.6 sec.

4. T_{ME} = Time for maximum message including errors and retransmission.

$$T_{ME} = \frac{\frac{N \bullet T_{SEL}}{1-P_S} + T_M + \frac{T_{VER}}{1-P_V}}{1-P_M}$$

where

N = number of nodes per SAS circuit

P_S = probability of error in selection = $1 - (1-P_B)^{64} = 1 - .9989$

P_V = probability of error in selection = $1 - (1-P_B)^{64} = 1 - .9989$

P_M = Probability of error in message = $1-(1-P_B)^{1920i+8} = 1 -.659$.

The value of T_{ME} in seconds for several values of N are:

N	3	6	9	10	15	20
T_{ME}(secs)	17.9	19.7	21.6	22.2	25.2	28.3

5. I.R.$_B$ = Information Ratio for broadcast

Information Ratios for transfer of large broadcasts are defined as:

$$I.R._B = \frac{T_{100}}{T_{ME}}$$

where

T_{100} = time in seconds at 100 percent information level (2400 b/s) to transmit maximum message = 10.2 seconds.

This gives the information ratios:

N	3	7	9	10	15	20
I.R.B.	.57	.52	.47	.46	.40	.36

L.5 SAS Poll Procedure

The concentrator will poll the SAS nodes during the A1, A2, and the A3 scan and at any other time during which it is not engaged in broadcast. ANSI X3.28-2.7, category A4 calls for sending a polling signal to a node which then responds with a message (Request or Weather Data) or it responds with an EOT to end transmission if it has no input to send. If the node inputs a message, then the controller responds with an ACK or NAK. If the message is a request, the controller forwards the request through NADIN to the WMSC and awaits its reply. Simultaneously, the concentrator resumes polling. When a reply is received at the concentrator, the polling is interrupted and the requesting node is selected by the concentrator and a verification request signal is sent to the node. If a reply is received in error by an SAS controller, then the reply is repeated in its entirety (assuming it is less than 3000 characters) at the end of the current polling cycle.

Several of the key parameters in the polling procedure are analyzed below.

6. T_{NP} = time for concentrator to complete one negative poll. To poll a station the concentrator will send

S	S	S			E	N	N
Y	Y	Y			N	U	U
N	N	N	*	U	Q	L	L

an 8 character message.

The station having no input responds with

S	S	S	E	N	N
Y	Y	Y	O	U	U
N	N	N	T	L	L

a 6 character message.

The time

$$T_{NP} = t_6 + t_2 + t_3 + t_4 + t_7 + t_2$$

where

t_6 = time to transmit poll characters = .027 sec.

t_7 = time to send EOT = .02 sec.

t_2, t_3, and t_4 are from p. L.8.

This shows that

T_{NP} = .194 seconds.

7. T_{PP} = time for concentrator to send a positive poll.

This time includes the time until the last character of the poll has been received by the SAS controller.

T_{PP} = $t_6 + t_2$ = .047 seconds.

8. T_C = time to collect an S.A. (ignoring errors).

This will include the time from the receipt of the last character of polling signal at the SAS node to the receipt of the last character of the input and the ACK message from the controller. To send an SA of 48 characters to the concentrator a node sends:

S	S	S	S			E	B
Y	Y	Y	T	S	———TEXT———	T	C
N	N	N	X	N		X	C

a message of 55 characters.

The concentrator responds with the 8 character ACK or NAK. Thus, T_C can be calculated as:

$$T_C = t_3 + t_4 + t_8 + t_2 + t_5 + t_2$$

where:

t_3 = terminal response to signal = .1 sec.

t_4 = modem turn on time = .007.

t_2 = local propagation = .02 sec.

t_8 = time to send SA = .183 sec.

t_5 = time to send ACK = .027 sec.

These values produce:

T_C = .357 seconds.

9. T_{CE} = time to input an SA if errors and retransmissions are considered.

$$T_{CE} = \frac{T_C}{1-P_C}$$

where

P_C = probability of an error in the SA transmission = $1-(1-P_B)^{440} = 1-.9927$.

This yields:

T_{CE} = .36

10. $I.R._C$ = information ratio for schedule of collection. This ratio is defined by:

$$I.R._C = \frac{T_{100}}{T_{CE}}$$

where

T_{100} = time to transmit the 48 character SA at 100 percent efficiency using 2400 b/s line = .16 sec.

Hence

IR_C = .44

11. T_{RQ} = time to send a request to concentrator and receive acknowledgement of successful transmission (errors are ignored in this term) To send a request in response to a poll signal, the SAS node transmits

S									S		I	E	B
O	S	T	N	N	N	N	> DTG	<<= R	T	V > ---Text---	D	T	C
H	N								X			C	C

The average length of such a message is 56 characters, of which 30 are request characters. This makes it possible to compute:

$$T_{RQ} = t_3 + t_4 + t_8 + t_2 + t_5$$

where

t_8 = time to transmit 56 character request message = .187 sec. and

t_2, t_3, t_4 and t_5 are as above.

This gives:

$$T_{RQ} = .341 \text{ seconds.}$$

12. P_{RQ} = probability of an error in transmitting request. P_{RQ} can be computed from the bit error rate P_B via:

$$P_{RQ} = 1 - (1-P_B)^{448} = 1 - .9925$$

13. T_{RP} = time for concentrator to send reply message to node from end of successful selection of that node (ignoring errors). After selecting a node via the selection process, the concentrator sends:

S									S		E	B
O	S	T	N	N	N	N >	DTG	<< R	T	---Reply---	T	C
H	N								X		X	C

Since an average reply is 690 characters, the average reply message will be 707 characters. T_{RP} can now be expressed as

$$T_{RP} = t_2 + t_9 + t_4$$

where

t_9 = time to transmit 707 characters = 2.36 seconds and t_2 and t_4 are the usual overheads given previously. This yields:

T_{RP} = 2.39 seconds.

14. P_{RP} = probability of an error in the transmission of a reply. P_{RP} is given by the formula:

$$P_{RP} = 1 - (1-P_B)^{5656} = 1 - .9098 = .0902$$

15. $P_S = P_V$ = probability of error in a selection or verification.

$$P_S = P_V = 1-(1-P_B)^{64} = 1 - .9989 = .001.$$

16. μ_{RQ} = mean service rate for request/sec. The values of μ_{RQ} for peak hour are included for completeness here.

N	3	6	10	15
μ_{RQ}	.27	.25	.23	.21

17. $\lambda_{RQ} = \lambda_{RP}$ = arrival rate of requests/replies at node or controller in arrivals per second for peak hour using 50 minute hour.

18. μ_{RP} = mean service rate in replies/sec. in peak hour = .33. This quantity is independent of the number of nodes.

NUMBER OF NODES/CIRCUITS	3	6	8	9	10	15
MST_{RQ} (SEC)	.59	.88	1.07	1.17	1.27	1.76
MST_{RP} (SEC)	3.07	3.07	3.07	3.07	3.07	3.07
λ_{RQ}	.0354	.0708	.0944	.1062	.118	.177
λ_{RP}	.0354	.0708	.0944	.1062	.118	.177
μ_{RQ}	.2735	.2532	.2413	.236	.23	.207
μ_{RP}	.33	.33	.33	.33	.33	.33
ρ_{RQ}	.1311	.2832	.3913	.45	.513	.856
ρ_{RP}	.1073	.2145	.286	.322	.3576	.536
W_{RQ}	.55	1.58	2.664	3.47	4.58	28.7
W_{RP}	.37	.838	1.23	1.46	1.71	3.55

TABLE L-1 LOCAL ACCESS SAS REQUEST/REPLY QUEUEING PARAMETER VALUES

APPENDIX M

REQUEST/REPLY MULTIPOINT CIRCUIT PERFORMANCE MODEL

The average delays D_{RQ} for a request and D_{RP} for a reply shown in Table 4-12 are derived below from the formulas:

$$D_{RQ} = MST_{RQ} + W_{RQ}$$

$$D_{RP} = W_{RP} + T'_{RP}$$

where

MST_{RQ} = mean service time for a request

W_{RQ} = queueing wait for a request (polling wait)

W_{RP} = queueing wait for a reply at the concentrator

T'_{RP} = time to send first character of reply to DTE = .1 sec.

M.1 Request Queue

A request arriving at a terminal experiences a wait due to polling and due to use of the line for another request or reply. The quantities MST_{RQ} and MST_{RP} are both needed to calculate queueing wait for requests. Specifically, MST_{RQ} can be expressed as

$$MST_{RQ} = \frac{(N-1)}{2} \bullet T_{NP} + T_{PP} + T_{RQ}$$

where

T_{NP} = time to conduct a negative poll = 6 sec.

T_{PP} = time to conduct a positive poll = 1 sec.

T_{RQ} = time to transmit request to concentrator = 3.6 sec.

The values of T_{NP} etc. are derived in Section M.3.

The quantity MST_{RP} consists of transmission time only and its value is

MST_{RP} = 69.6 seconds.

The values of W_{RQ} the queueing wait experienced by a request can now be computed and are given as follows:

N	2	3	4	6	8
W_{RQ}(secs.)	11.5	20	31.6	72.3	166

The formula for W_{RQ} in an M/M/1 queue is

$$W_{RQ} = \frac{1}{\mu_{RQ}} \bullet \frac{\frac{\lambda_{RQ}}{\mu_{RQ}}}{\left(1 - \frac{\lambda_{RQ}}{\mu_{RQ}}\right)}$$

where

μ_{RQ} = service rate in peak hour = $(MST_{RQ} + MST_{RP})^{-1}$

λ_{RQ} = arrival rate in msg./sec. in peak hour = (.00083)N

The values of μ_{RQ} and λ_{RQ} are given in Table M-1 for N = 2, 3, 4, 6, 8.

M.2 Reply Queue

A reply arriving at a concentrator will be immediately sent to the appropriate terminal unless the line is occupied by a reply transmission or unless other replies precede the new reply in the queue. The reply does take precedence over polling and request input, however.

The values for W_{RP}, the queueing wait experienced by a reply at the concentrator, are given below:

N	2	3	4	6	8
W_{RP}(secs.)	9.1	13.0	20.7	37.2	60.5

The formula for W_{RP} is:

$$W_{RP} = \frac{1}{\mu_{RP}} \bullet \frac{\frac{\lambda_{RP}}{\mu_{RP}}}{(1 - \frac{\lambda_{RP}}{\mu_{RP}})}$$

where

μ_{RP} = service rate in peak hour for reply = $(MST_{RP})^{-1}$

λ_{RP} = arrival rate in msgs./sec. in peak hour = (.00083)N.

The values of μ_{RP} and λ_{RP} are given in Table M-1.

M.3 Request/Reply Low Speed Protocol and Queueing Parameters

The local concentrator will continuously poll each Request/Reply circuit. The poll procedure will be essentially that now used by the WMSC. This means a 10 character polling signal is sent to each terminal. If a terminal has no input it remains silent for 5 seconds.

The concentrator then polls the next terminal and so on. A reply received at the concentrator is sent directly to the appropriate terminal with no selection process required unlike the SAS protocol.

The values of some of the parameters discussed in Sections M.1 and M.2 are derived below.

1. T_{NP} = time of negative poll = $t_p + t_o$

where

t_p = time to transmit 10 poll characters = 1 sec.

t_o = time out as negative response $\approx$ 5 sec.

2. T_{PP} = time of positive poll $= t_p$ = 1 sec.

3. T_{RQ} = time to transmit average request of 30 characters = 3.6 sec.

$T_{RQ} = t_1 + t_2$

where

t_1 = time for 30 character request $\approx$ 3 seconds.

t_2 = time for end of transmission characters = .6 seconds.

4. T_{RP} = time to transmit average reply of 690 characters = 69.6 sec.

$T_{RP} = t_2 + t_3$

where

t_3 = time for 690 character transmission = 69 seconds

t_2 = EOT transmission time = .6 sec.

5. λ_{RQ} = λ_{RP} is the mean arrival rate in message/sec. during peak hour for requests at a terminal or replies at a concentrator.

$$\lambda_{RQ} = \left(\frac{1}{3600}\right) + A_H \bullet N$$

where

A_H = number of requests per peak hour per terminal = 3

N = number of nodes per circuit

6. μ_{RQ} = service rate for requests per second in peak hour

$$\mu_{RQ} = (MST_{RQ} + MST_{RP})^{-1}.$$

where MST_{RQ} and MST_{RP} are from Section M.1 and M.2.

7. μ_{RP} = service rate for replies per sec. in peak hour.

$$\mu_{RP} = (MST_{RP})^{-1} = .0144$$

N=NODES/CKT	2	3	4	6	8
MST_{RQ}	7.6	10.6	13.6	19.6	25.6
μ_{RQ}	.0129	.0125	.012	.0112	.0105
λ_{RQ}	.00176	.00249	.0033	.0050	.0067
ρ_{RQ}	.1364	.1992	.275	.446	.638
MST_{RP}	69.6	69.6	69.6	69.6	69.6
μ_{RP}	.0144	.0144	.0144	.0144	.0144
λ_{RP}	.00176	.00249	.0033	.0050	.0067
ρ_{RP}	.122	.173	.2292	.347	.4653

TABLE M-1 LOCAL ACCESS REQUEST/REPLY QUEUE PARAMETERS

APPENDIX N

SERVICE A TRAFFIC CLASSIFICATION

All terminal and communications nodes in the Area A and Request/Reply population require connectivity with the one resource node - the WMSC. The communications utility providing this connectivity must support three broad functional information exchange classes:

- Collection
- Dissemination
- Database Query

The database query function is applicable to both the Request/Reply terminal nodes and the SAS controller communications nodes, while the collection/dissemination function is applicable to the Area A terminal nodes and the SAS cluster controllers. The collection/dissemination functions produce three types of traffic:

- Scheduled - messages sent during a fixed time period and always anticipated by the WMSC.
- Unscheduled - messages sent at random within a session for which start time is defined.
- Priority - urgent messages sent at random and given a degree of priority for relay purposes.

The database query function results in an interactive traffic which is generated on a random bas ‹. Table N-1 summarizes the nodal connectivities, functional class, and traffic types while Figure N-1 presents a conceptual display of traffic flow.

N.2 Traffic Description

Traffic descriptors must provide definition of the activity level to be supported by the communications utility. The key parameters are message length and interarrival time distributions. It is important to make reasonable assumptions with regard to formulating these parameters. For message length, a random nature is usually postulated and one of the following probability functions used to describe the message:

- uniform distribution
- exponential distribution
- biased exponential distribution
- gaussian distribution.

Unlike the message length distributions in question, which have no messages of deterministic length, the arrival distributions are both deterministic and probabilistic. The deterministic messages are previously referred to as scheduled while the probabilistic are referred to as unscheduled, priority, and Request/Reply. The probabilistic are assumed to have exponential interarrival distributions.

Traffic T1: Scheduled Collection

Hourly surface meteorological observations (SA) are filed with stations having sending capability for transmission to the WMSC at H+00 of every hour. This is called the A1 scan of the WMSC. The interarrival times are of a deterministic nature while the length distributions are assumed gaussian. This traffic has a life of 1 hour.

Traffic T2: Unscheduled Collection

A wide variety of weather products are transmitted for which the WMSC has no a priori knowledge. These transmissions occur at specific times but the receipt is unexpected. The tansmissions occur at H+21 and H+39 of each hour (called the A2 & A3 scan). The

arrival during these sessions are probabilistic with exponential distribution and, with one exception, all have gaussian length distributions. Some of this traffic has a life of 1 hour while others are in the system until cancelled.

Traffic T3: Priority Collection

At any time during the hour a station may send an urgent message that takes precedence over the scheduled and unscheduled traffic both in transmission and placement in the queue of the WMSC. This traffic is very time critical and can not tolerate long delays. Its arrivals are exponential over the entire hour and the length distributions gaussian.

Traffic T4: Scheduled Dissemination

The WMSC stores surface observations (SA) and several other classes of meteorological observations until H+59 of each hour. These reports are then expunged in anticipation of new reports. The lifetime of this traffic ranges from one to three hours, the bulk being SA's for which the life is 1 hour. Distribution is in accordance with a specific list which correlates to a receive stations propinquity to the originator.

Traffic T5: Unscheduled Dissemination

During the times that the WMSC is not scanning or engaged in a scheduled broadcast, the WMSC is available for unscheduled broadcasts. A wide variety of weather products and airport conditions are broadcast that are received from many non-FAA facilities such as NWS and WSFO's. Their interarrival statistics at the receive stations are varied exponential distributions while the length distributions are biased exponential and gaussian. The life of this traffic ranges from one to many hours with some remaining valid until cancelled.

Traffic T6: Priority Dissemination

In addition to the traffic T3 (Priority Collection) this traffic includes that from other sources such as the NWS.

T7: Database Queries - Requests

Other than priority traffic, requests and replies are the only non-session oriented traffic under consideration. These requests originate from an FSS when a Flight Specialist needs information other than what is routinely disseminated to his station. This need occurs when briefing a pilot whose proposed flight leaves the general geographic area. As a consequence, flight briefs in large cities will usually require more Request/Reply service per unit pilot brief as many of these flights will leave the general area. The message requests have exponential interarrival and length distributions. This is interactive traffic and time critical.

T8: Database Queries - Replies

A reply results from each valid request. The message length is also exponentially distributed, however, the average reply is usually an order of magnitude larger than the request. Likewise this is interactive traffic and time critical.

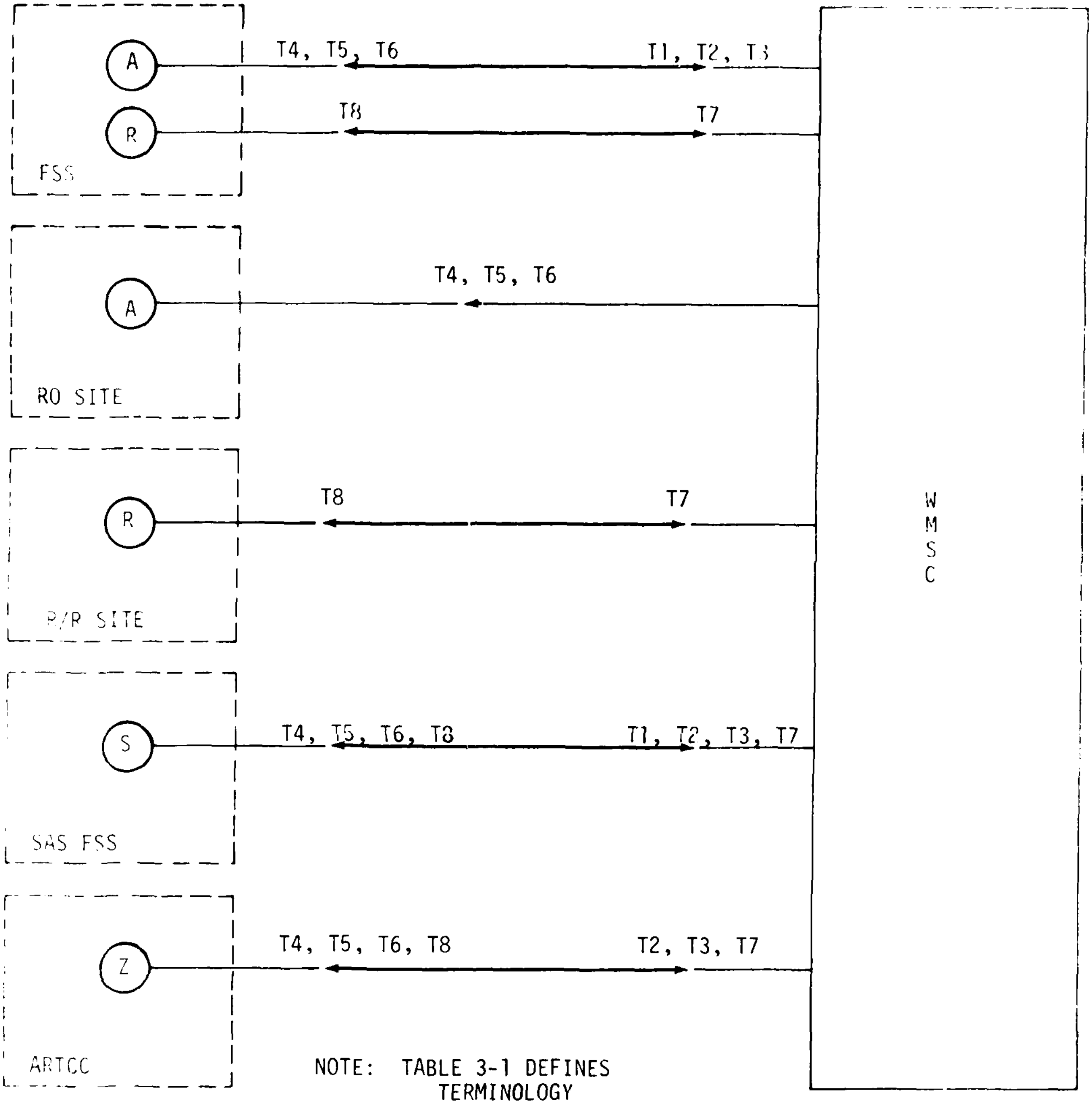

Figure N-1: CONCEPTUAL DISPLAY OF TRAFFIC FLOW

TRAFFIC DESIGNATOR	SOURCE NODE	SINK NODE	CLASS	TYPE
T1	S, A	W	COLLECTION	SCHEDULED
T2	S,A,Z	W	COLLECTION	UNSCHEDULED
T3	S,A,Z	W	COLLECTION	PRIORITY
T4	W	S,A,Z	DISSEMINATION	SCHEDULED
T5	W	S,A,Z	DISSEMINATION	UNSCHEDULED
T6	W	S,A,Z	DISSEMINATION	PRIORITY
T7	S,R,Z	W	DATABASE QUERY	REQUEST
T8	W	S,R,Z	DATABASE QUERY	REPLY

KEY:
A - Area Terminal
R - Request/Reply Terminal
S - SAS Controller
Z - ARTCC Terminal
W - WMSC

Table N-1: TRAFFIC CLASSIFICATION BY CONNECTIVITY FUNCTION, AND TYPE

APPENDIX O

BUSY DAY FACTOR

A daily report from the WMSC system was provided by a WMSC systems analyst. Subsequent discussion revealed the following:

- the daily report provided was for a "usual day" for which the WMSC had a throughput of 1.56×10^8 characters or an average of 6.5×10^6 characters per hour
- on "busy days" the average throughout is over 7×10^6 characters per hour. This allows the calculation of the peak day factor, D_P. To be conservative the peak hour is chosen to be 8×10^6 characters per hour therefore;

$$D_P = (8 \times 10^6) / (6.5 \times 10^6) = 1.23$$

The daily report provided both input/output characters on a per circuit and per station basis for Area A, Request/Reply, SAS, and dedicated center circuits.

APPENDIX P

REQUEST/REPLY PEAK HOUR TRAFFIC MODELS

P.1 SAS Request/Reply Peak Hour Traffic

The concept of a peak hour for Request/Reply is based on discussion with an FSS specialist which indicated that there are 3 peak hours in the morning and 2 peak hours in the afternoon during which traffic volume is approximately 4 times normal hour. This gives the equation:

$$5(4y) + 16\,y = H$$

where

y	=	requests per normal hour in entire Service A;
$4y$	=	requests per peak hour in entire Service A
H	=	total requests per day = 24,491.

This equation yields:

$$4y = .11\,H = 2798 \text{ requests/peak hour.}$$

Each of the 1156 KVDT's attached to an SAS controller will be assumed to generate the same number of requests as a low speed Request/Reply terminal. This gives a total of 1345 KVDT equivalents generating requests.

On average there are 7.7 KVDTs per SAS controller. Therefore the number of requests per peak hour for an average SAS node is given by

$$R_p = 4y \bullet C_p \bullet D_p \bullet G_F \bullet \frac{K_n}{K_v}$$

where

R_p = number of requests/SAS controller per peak hour;

$4y$ = total requests per peak hour received at WMSC = 2798

C_p = busy center factor = 1.5

D_p = peak day factor = 1.23

G_F = growth factor = 1.20

K_N = number of KVDTs per SAS node = 7.7

K_v = total number of KVDT equivalents = 1345

which yields

R_p = 35.4 requests/SAS node per peak hour.

P.2 Request/Reply Low Speed Peak Hour Traffic Model

The analysis above requires only slight modification to obtain peak hour traffic for low speed R/R models. The peak hour concept is the same as above and the quantity 4y = 2798 Requests/Peak hr. can be used to obtain N_p by writing:

$$N_p = 4y \bullet D_P \bullet \frac{G_F}{K_V}$$

where

N_p = number of requests per peak hour per terminal;

D_p = peak day factor = 1.23

G_F = growth factor = 1.2

K_v = total number of KVDT equivalents = 1345.

This yields:

N_p = 3.07

The factors D_p, G_F, K_v are the same as those in Section P.1. Note that no busy center factor was used because most higher activity Request/Reply low speed terminals will have been replaced by SAS facilities by 1982.

APPENDIX Q

NADIN 1 CONCENTRATOR TRAFFIC

ID	Port Type	No. of Lines	Input to Concentrator				Output From Concentrator			
			Message Type	Account?	MSG/HR Total	CPS Total	Message Type	Account?	MSG/HR Total	CPS Total
Switch	1	1	II III II	Y N N	666 14 90	22 11 3	II II	Y N	685 90	23 3
9020	2	1	II II	Y N	301 30	10 1	II III II	Y N N	312 4 30	10 3 1
FOT	3	1	II	N	5	1	II	N	5	1
Local DTE	4	1	II II	Y N	8 2	1 1	II II	Y N	8 2	1 1
Remote DTE	5	2	II II	Y N	160 40	5 2	II II	Y N	160 40	5 2
Area B	6	4	II II	Y N	51 13	2 1	II II	Y N	51 13	2 1
Mil. B	7	1	II	Y	1	1	II	Y	1	1
AFTN	8	2	II	Y	60	2	II	Y	60	2
Air B & Util B	9	1	II	Y	14	1	II	Y	14	1
MAPS	10	1	II	Y	60	2	II	Y	60	2
INT'L AFTN	12	1	II	Y	30	1	III	N	10	8
TOTAL		16		Y N	1351 194	47 20		Y N	1351 194	47 20

TABLE Q-1: LEVEL I - CONCENTRATOR

APPENDIX R

NADIN I SWITCH TRAFFIC

			Input to Switch				Output From Switch			
ID	Port Type	No. of Lines	Message Type	Account?	MSG/HR Total	CPS Total	Message Type	Account?	MSG/HR Total	CPS Total
Concentrator	1	12	II II	Y N	8223 1080	275 36	II III II	Y N N	7998 168 1080	267 140 36
WMSC	14	1	II II III	Y N N	336 780 48	11 26 40	II II	Y N	336 780	11 26
Int'l AFTN	16	4	II	Y	240	8	II III	Y N	440 40	14 33
NWS	17	1	II III	Y N	440 160	14 133	II	Y	600	20
Switch	20	2	II II	Y N	2355 324	79 11	II II	Y N	2355 324	79 11
Dial-Up TTY	25	3	II	Y	120	4	II	Y	120	4
Airlines B	26	1	II	Y	150	5	II	Y	15	1
TOTAL				Y N	11864 2392	396 246		Y N	11864 2392	396 246

TABLE R-1: LEVEL I - SWITCH, PART 1